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Digital Divide: Can Computer and Videogame Usage equalize the Gender differences in Mental Rotation Ability?

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Abstract

Many studies with different settings have confirmed that there is a performance difference in spatial skills between men and women, especially in the domain of mental rotation. The mental rotation performance is influenced by many different factors, such as training, sexual orientation, age, hormonal level or psychological influence.
Video game usage positively affects the performance on mental rotation tasks and as this special form of training is favored by men, this training gap could possibly be identified as main influencing factor. Question is whether the digital divide in video game usage widens or slowly disappears. Currently men are better trained because of their choice of video games and the amount of time invested in training. As the performance gap is not perceivable when the mental rotation test deploys real 3-dimensional figures instead of 2-dimensional representations of 3-dimensional figures. It might be possible that the advent of 3D presentations evens out the MR performance gap. Statistics are showing that the amount of game playing females has risen over the years. The creation of appealing game titles for women, which are exercising spatial skills, could balance this training difference and along with it the stability of different performance levels in mental rotation tasks between men and women.

Keywords

Digital Divide, Mental Rotation Ability, Spatial Ability, Computer Experience, Video-game Training, Gender Difference

1. Introduction

Spatial abilities are the cognitive processes of locating targets in space, understand distance and directional relationships, and mentally transform objects in space. Spatial ability is a prerequisite in many domains of nowadays life, finding routes, orientate on maps, installing electronic equipment, surgery, (Terlecki & Newcombe, 2005) and many more.
Spatial ability can be separated into the subcategories mental rotation ability, spatial perception, spatial visualization, object location memory and dynamic spatial ability. With exception of the task of object location, men perform better than women in spatial tasks, (Lawton, 2010) the sub domain of spatial ability where the measurable gender gap occurs the greatest, is the mental rotation ability. (J. C. Yang & Chen, 2010) These differences are occurring robustly on several studies realized on this topic. There are many aspects influencing the performance; the hormonal level, sexual orientation, psychological influence, age, and of course video game training.
Especially video game training is interesting. It positively affects the mental rotation ability and it is a fact that men more frequently play video games and prefer different kind of games than women, offering them better training of spatial abilities. The different level of video game training could therefore be seen as main reason for the performance gap.
Question is to what extend does the digital divide in computer-game usage influences the gender difference in mental rotation ability, may it foster or vanish.

2. Mental Rotation Ability

Mental rotation is a special task of spatial ability. A good performance in mental rotation tasks also assumes good performance in topics as geometry, mathematics, chemistry and physics (Moe, 2009) and is also important for orientation or finding a route on a map. (Malinowski, 2001) Mental rotation is the ability to understand how a representation of an object would look if it is turned around in two- or three-dimensional space. The mental rotation test was originally developed by (Shepard & Metzler, 1971) and adapted by (Vanderberg & Kuse, 1978) (Figure 1). The task is to find the matching representations of an object out of a set of four objects. Two of these objects are rotated representations of the object to identify, one is a distractor and the other one is a mirror-image of the comparison figure. (Vanderberg & Kuse, 1978) Among different mental rotation tests, this one reveals the greatest performance difference between the sexes. (Geiser, Lehmann, & Eid, 2008)

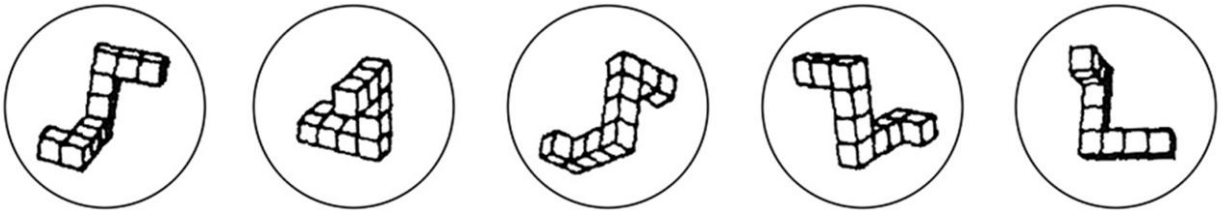

Figure 1: Mental Rotation Test (Vandenberg & Kuse 1978)
Source: (Moe, 2009)

2.1. Gender differences in Mental Rotation Ability

Men outperform women in MR task in terms of accuracy and speed of problem solving. (Terlecki & Newcombe, 2005) This performance gap is one of the largest known cognitive sex differences and has been proved to be reliable by several studies and is detectable across different cultures. (Silverman, Choi, & Peters, 2007) Although culture influences the performance (Chinese men were found to perform as accurate as American men, but their decision taking process took longer), (C.-F. J. Yang, Hooven, Boynes, Gray, & Pope, 2007) the gender difference remains stable.

The question about the reason for this phenomenon is difficult to answer; fact is that there are several factors influencing the performance. The social role theory suggests that the origins are physical sex differences, women were given the responsibility of nursing and caring for infants, and men were made responsible for hunting animals and warfare. This role separation creates gender stereotypes and associated gender appropriate behavior. (Eagly & Koenig, 2006)

A different level of training, especially video game training has strong influence on MR performance and it is more socially accepted that boys playing games than girls doing so (Jansz et al., 2010). Therefore the digital divide in terms of computer game usage could be seen as main influencing factor on training possibilities and accordingly MR performance.

2.1.1. Sexual orientation

The sexual orientation of a person influences their mental rotation ability. In a study with female participants, the group of not strictly heterosexual women performed better than the strictly heterosexual women. (van Anders & Hampson, 2005)

Sex hormones influence the spatial perception through organizational effects that is the differentiation of brain systems early in development and through the activation effects of the

hormones, which are influencing the spatial performance during life (Peters, Manning, & Reimers, 2007). Another study about performance differences among sexual orientations was conducted by (Peters et al., 2007). Men and women were asked to categorize themselves as homosexual, bisexual or heterosexual and take a MR test. The result produced a ranking in terms of performance where heterosexual men found to perform best, followed by bisexual men and by homosexual men. The worst performing group of men was still performing better than the best performing female group, the homosexual females. Within the female subset, the ranking is the men's upside down, the group of homosexual women performing best, followed by the bisexual and by the worst performing group, the heterosexuals women.

2.1.2. Hormonal influence

The gender performance difference in spatial ability is even consistent among animals; male rats demonstrate better spatial abilities than their female peers. Male rats, which where castrated at birth do not perform better than female rats, whereas female rats, treated with a metabolite of testosterone at birth, could improve their skills. (Lawton, 2010) But different testosterone levels do not serve as a reliable indicator for performance. (Puts et al., 2010)

The menstruation cycle also affects mental rotation performance; women in the luteal phase of the menstrual cycle performed worse that the menstrual group, the follicular group and the group of women using the birth-pill. (Peters et al., 2007) External hormonal influence in form of oral contraception influences mental rotation performance; women using a birth control pill are performing better than women that do not use it. This effect is only true for the birth-combination pill, the mini-pill, which includes no estrogen, does not seem to influence the MR performance. (Peters et al., 2007)

2.1.3. Psychological Influence

Male priming shows a positive effect on spatial skills in women. Priming is a method to stimulate stereotypical representations in the cognition and thereby activate stereotypical behavior. In their study (Ortner & Sieverding, 2008) exposed their participants either to female or male stereotypes. The group being subject to the male stereotype activation performed better than the other groups, and male priming could even neutralize the performance difference of the sexes.

2.1.3. Age

(Geiser et al., 2008) have investigated whether the sex differences are changing for different age groups and whether these differences increase with age. The participants were separated into 15 different age groups (9-23 years). They found that the difference for both genders increases as a function of age. Males scored higher than females in all age groups. An explanation for this effect might be that males are more involved in spatial activities than are females, since their early childhood, as sex differences even exists in the age group below 13 years. But you have to keep in mind that there is a gigantic technology gap between a teenager in 2011 and her grandpa at the same age. The older people grew up under different conditions where there was no computer-game training, or computers were not as easily available as nowadays. Therefore it is not reasonable that they received the same amount of training of younger people.

2.1.4. Different test characteristics

The test character influences the performance as well, during a two week training period, (Neubauer, Bergner, & Schatz, 2010) found that there are differences between the mental rotation performance of a 2-dimensional and a 3-dimensional representation of an object. The described performance gap between men and women only appears in the 2-dimensions version and not in the 3-dimensional one. It might be possible that the female disadvantages lies in the derivation of a 3-dimensional representation from a 2-dimensional image. It might also be

possible that men have already had better skills for solving 2D tasks. With training men can automatize these skills and women can develop the rudimentary skills, boys already have. (Neubauer et al., 2010) That a virtual environment test eliminates the gender gap in comparison to a paper and pencil test (2-dimensional) (Parsons, 2004) is very interesting. In the virtual environment test settings, the shape was projected like a hologram, thus appearing in real dimensions in opposite of the 3-dimensional Shepard & Metzler figures, which are only perceived three dimensional, but as they are rendered only in two dimensions, they are more "quasi – 3D" (Deręgowski, 1979)

2.2. Gender differences in computer game training

In an early stage of education, the access to computers differs among the sexes, males are taking over the computer, they appropriate them as their own and thus the girls' access is restricted. (Cassell, 1998) Computer video gaming serves as a starting point for general computer usage as it enhances general computer-related knowledge and interest. As the bulk of computer gamers are men, the gender difference in access to information technology fosters. (Hartmann & Klimmt, 2006) Most digital entertainment games reflect stereotypical male interest, presented in a violent context and female characters often serve as eye-catcher. (Jansz et al., 2010)

2.2.1. Different amount of training

The question is to what extend the MR performance gap is consequence of the mentioned influence factors. Training might be most powerful influencer and male users are more likely to be "educated" with computer game usage, where imagination and spatial analysis are trained from an early stage. The different level of computer game usage might be influenced by social roles. Women in general, show less interest in computer gaming and when they play, they do not invest as much time as males and they play less frequently. (Hartmann & Klimmt, 2006)
The executive summary of their study about video gamers in Europe (Dromgoole & Parker, 2010) shows that 31 % of males and 20% of females are Gamers (Figure 2); still, male and younger gamers are more likely to spend time and money on gaming.

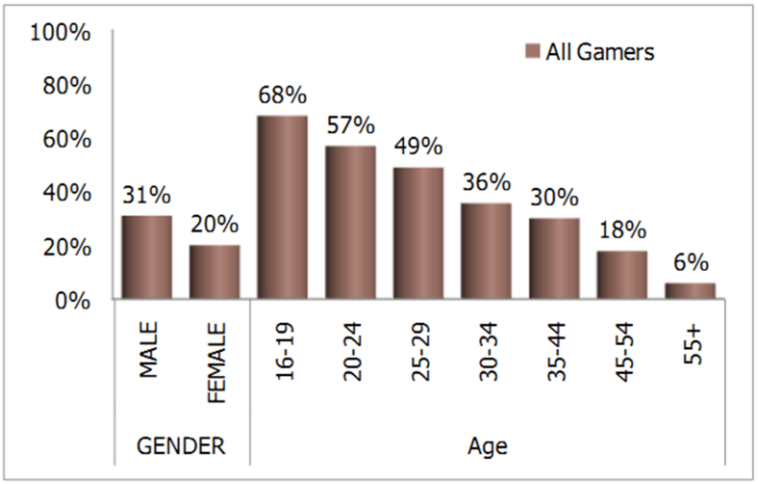

Figure 2: European gamer's population
Source: (Dromgoole & Parker, 2010)

2.2.2. Different choice of game type

It depends on the individual game genre, how much benefit in terms of spatial ability gaming can generate. Action video games are bringing the greatest benefit. After a ten hours training with an

action video game, gender differences in spatial attention as well as in the mental rotation task are decreasing. Especially first-person shooter action games, which are mainly preferred by boys, are found beneficial to the players' spatial skills. (Feng, Spence, & Pratt, 2007) In their study they compared the games “Medal of Honor: Pacific Assault”, a 3D first person shooter game for the testing group and ballance, a 3D puzzle game for the control group. In the action video game group, the gender difference on the mental rotation task was much reduced, although not fully eliminated. Non-action games may less show this beneficial effect, as spatial skills are not exercised at the same extend. (Feng et al., 2007) But (Boot, Blakely, & Simons, 2011) arguing that these separation into an experiment and control group could activate placebo effects. If a training group plays Tetris extensively, the group members would assume that their training improves their mental rotation ability (Boot et al., 2011) and this effect could influence their performance as well. Although not being beneficial at the same amount, video game puzzle training does improve spatial abilities as well (Smith & Middleton, 2003) and puzzle games have been identified as the most popular type of online game for the weaker performance groups in terms of spatial abilities, the females and the group of older users from age 40-49. (J. C. Yang & Chen, 2010) But it is not possible to state that every puzzle game enhances spatial skills. Pentomino and Tetris are definitely useful for mental rotation skills, at least for the 2-dimensional mental rotation test. In their study (J. C. Yang & Chen, 2010) investigated the performance gain of a digitalized version of the game Pentomino (Wadsworth, 1970) on the spatial abilities. The games goal is to arrange a Pentomino (a shape that consists of five equal sized squares) within a frame in a predetermined way; therefore it is necessary to rotate or flip pieces and to select the appropriate ones out of all available pieces. Figure 3 demonstrates this task; players are to complete the figure with insertion of available shapes. As game pieces have to be rotated mentally in order to fit into the target shape, training with this game exercises the mental rotation ability and thus helps to equalize different levels of performance between men and women. (J. C. Yang & Chen, 2010)

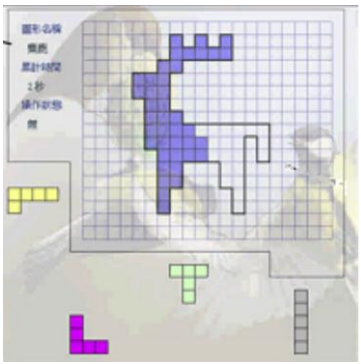

Figure 3: digital pentominos game
Source: (J. C. Yang & Chen, 2010)

2.2.3. Different gaming software and hardware preferences

Women prefer different kind of games than boys; they prefer games involving social interaction and problem-solving and tend to avoid typically men games, with violence, war simulation and combat. This seems to be due to gender norms, peer pressure and the masculine touch of these games (Hayes, 2011)

The reason for the imbalance between the amount of female and male players is partly fault of the computer game producers. Most digital games rely heavily on stereotypes, women are misrepresented as being weak and need to be protected or rescued by the dominant, powerful

male character, or they are portrayed with over emphasized sexual attributes. Female users generally show low appreciation for the described female characters, thus reducing their motivation for playing these games. (Hartmann & Klimmt, 2006) The problem is not the sexiness itself, but the weak character and the lack of leading roles in role playing games as well as misogynistic actions as part of the game design. (Delamere & Shaw, 2008) The male characters in an action game are idealized hyper-masculine characters, with stereotypical presentations of being tough, strong and machos. For most gamers it serves an enjoyment to control a character like that, having power over others, that is true for men and women as well, but opinions differ for the hyper-sexualized female characters. While most male players are accepting the portrayed image without concern, females are much more critical. (Delamere & Shaw, 2008) A broader range of representations of femininity within computer games will probably encourage more women to gaming. (Kennedy, 2002)

It is not only lack of motivation or deterring game design that keeps women from gaming. In this male dominated area, some people do not welcome female players; women are discriminated, attacked verbally or even detained from participation in tournaments through sabotage act against their hardware. (Delamere & Shaw, 2008)

There are also differences in the preference of gaming hardware between men and women, which is likely due to different kind of games that are developed for these devices.

Females were identified as top users of Nintendo's DS and Wii platform, at a ratio of 5:2 in comparison to male users, whereas Sony's platforms and Microsoft's Xbox 360 are dominated by male users. (Figure 4)

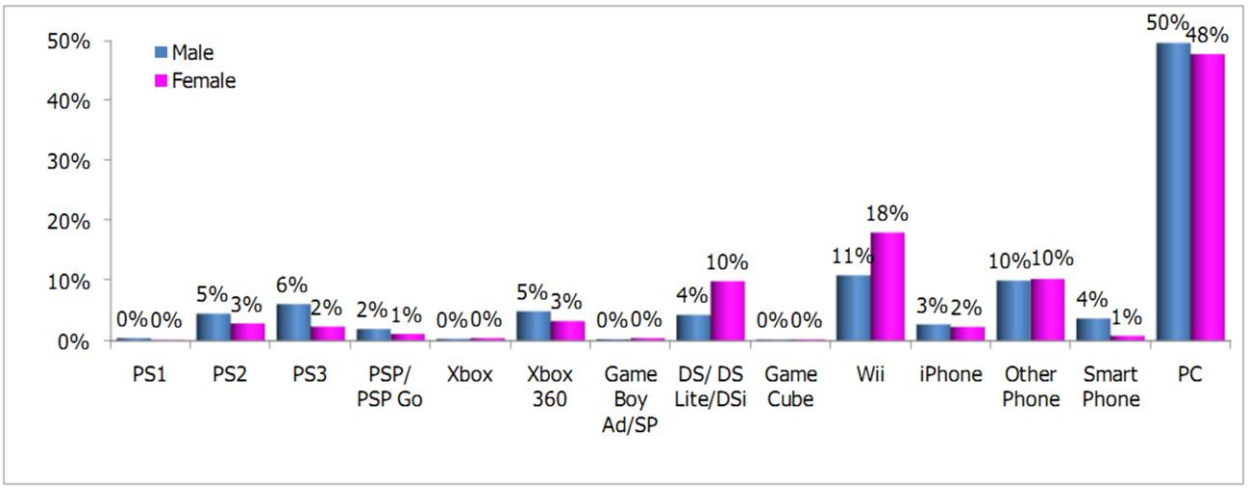

Figure 4: Reported Use of main System: Europe, By Gender
Source: (Dromgoole & Parker, 2010)

The best-selling games for the different gaming devices are approving this gender separation. Among the top ten best-selling games for Microsoft's Xbox 360, eight action shooters can be found and only one game without weapons and brutality, “Guitar Hero III”. (Listal.com, 2011a)

The genres for the top selling games on “female dominated” consoles like the Wii are very different; there are sport games, fitness games, mini-games and jump-and-run games. (Listal.com, 2011b)

2.2.4. Gender aligned game design

Although boys and girls can be equally skilled in computer experience, computers are considered to be boys' toys, serving a reason why computer games studios are producing games gearing toward their core customers, the males. A game producer said that he had more left handed

players than female, and he did not program games for left handed (Cassell, 1998), but that was at a time, when the potential amount of female gamers was not as high as nowadays where 42% of all players are women. The market potential is very high, the group of women age 18 and older is one of the fastest growing demographics, with 37% market share in comparison to 13 % for boys younger than 18 years. (esa, 2011) The efforts of cultivating female gamers are rising. But renaming the main character to, for example Ms. Pacman, does not make much sense and changing the visual appeal with pink game covers might possibly raise more female attention, but does not change the game play.

In order to attract women for gaming, two strategies can be followed; either design games specially targeted at women or adjust and modify computer games for being more appealing to women, making them transgender. (Corneliussen & Mortensen, 2005) An example for the first strategy is the very successful game "The Sims", actually being the best-selling PC game of all time, followed by "Sims 2" on the second place. (Makalinao, 2010) This game is said to be a role model for a game which attracts female players through a feminized social environment (caring and nursing for one´s sim) and the absence of stereotypical male game characteristics. (Jansz et al., 2010) As a result, 60% of its players are females. (Makalinao, 2010) But this game does not offer the same amount of spatial ability training, a 3d action shooter can generate, thus not being that helpful for improvement of mental rotation ability.

An example for the customization strategy is the game "Tomb Raider", where a strong, independent woman with over emphasized sexual attributes represents the main character, an action heroine. The idea of the producers was to attract gamers with the central character Lara Croft, a role model for girls and a sexually appealing depiction for the core market of male players. (Cassell, 1998) Lara perfectly matches the 90's "girl-power" zeitgeist. (Kennedy, 2002)

A probably unexpected development was the advent of so called nude patches, enabling the (male) players to navigate the character totally nude through the levels. (Chrissyx, 2010)

Violence is another factor that separates the preferences between the sexes; male users are seeking the emotional experience, positive emotions like pride and joy, as well as negative emotions like anger and fear. (Jansz, 2005) There are very few action games that can totally forgo violence, (Hartmann & Klimmt, 2006) and of course there is no action-shooter amongst them. Out of the top 10 best-selling games for the Xbox360, only one game without violence could keep up with the action-shooters. (Listal.com, 2011a)

Another attempt to enthuse women for computer-games is to involve them into the development process. In an experiment, women of elementary-school grade had to program a game with the help of a visual interface game programming tool. The tool, named Scratch was developed by MIT researchers and geared toward programming accessibility for young children. Although their game design experience was low, they learned quickly and developed social interaction and community about computing. (Baytak & Land, 2011)

Discussion

The mental rotation performance is influenced by different factors; some of them are possibly interrelated, for example the sexual orientation. An explanation for the performance difference might be that homosexual men do not "take advantage" of the activation of stereotypical male behavior, like heterosexual are doing. It is not clear whether sexual orientation influences computer usage, especially game training, but it might be possible that homosexual men do not like to play action-shooters at the same amount as heterosexual men, thus resulting in different spatial experience levels. (Neubauer et al., 2010) investigated that the performance gap is not valid for real 3-dimensional representations. In the nearer future, 3-dimensional representations are going to be everywhere, even nowadays game devices such as the Nintendo 3Ds are capable of displaying objects 3-dimensional, cinema movies are produced in 3D, TVs and even mobile phones are able to display 3-dimensional pictures. This development could smooth out the gender gap in the nearer future, as the mental rotation ability will likely get tested with 3D

technology, where mental rotation performance differences between the sexes are found to be much smaller. Although the performance difference between the sexes remained stable over a 17 years' time span (1975-1992) (Masters & Sanders, 1993) I think that new technology and a weakening role separation, will much reduce the performance gap.
Some spatial skills like navigation with a 2-dimensional representation like a map are going to become needless because of the occurrence and practicality of modern navigation systems and the omnipresence of GPS. Another point is the access to computers and thus "training" that becomes easier and easier. Smartphones are posing a severe thread for the gaming console producers, their massive distribution and free or inexpensive games, have already detached billions of dollars of game revenue. (Valadares, 2011). As these devices are always ready and games are available for free, children are very likely to use them for gaming purpose, no matter what sex they are.
The social role separation is also very likely to reduce in the nearer future, it will be more socially accepted that women are playing computer games and own computers.
As the female population nowadays represents an important market share, game producers are going to incorporate women's conceivability into new games, thus attracting even more women for gaming. This "training" compensation between men and women is probably going to even out the gender difference in MR, although the gender difference was found to be stable until 1993, much have changed since then.

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