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Sex Differences in Spatial Abilities: Biological and Evolutionary Psychological Explanations

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Bachelor Degree Project in Cognitive Science C, 15 ECTS

Spring 2008

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Submitted by Erica Wendelholt to the University of Skövde, as a dissertation towards the degree of B.Sc. by examination and dissertation in the School of Humanities and Informatics. Supervised by Katja Valli.

2008-06-11

I hereby certify that all material in this dissertation which is not my own work has been identified and that no work is included for which a degree has already been conferred on me.

Signature:_____

Abstract

Sex differences in spatial ability, especially mental rotation, navigation and object-location memory are described in this essay. Biological differences in brain morphology, hormones and genes between men and women are presented as explanations for the sex differences. Another level of explanations offered are evolutionary, hence the most influential evolutionary psychological theories are summarized and evaluated. These theories are Gaulin's and Fitzgerald's male range theory, Silverman's and Eals's hunter-gatherer theory, and Ecuyer-Dab's and Robert's twofold selection theory. The hunter-gatherer theory at present seems to be of the most importance, though the twofold selection theory may in the future challenge it. Regardless, united biological and evolutionary explanations would create the best comprehensive theory.

Keywords: spatial ability, sex differences, evolutionary psychology

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Introduction

Evolutionary psychology (EP) tries to explain psychological processes, behaviours, reactions and responses to the environment from an evolutionary perspective. Thus it describes all areas of psychology, such as personality, perception, learning, emotions, social abilities and other cognitive traits of humans. To do so, evolutionary psychologists use Darwin's ideas of natural and sexual selection through which adaptation to environmental selection pressures takes place (Gaulin & McBurney, 2004).

EP often discusses the environment of the evolutionary adaptedness (EEA), referring to the time and environment (though it cannot be said to be a specific time or place) when humans lived as hunters and gatherers. It was then that the humankind evolved, before the domestication of plants and animals (Gaulin & McBurney, 2004). Most importantly, during the EEA adaptations were shaped, due to natural and sexual selection pressures.

"The principal aim of EP is to understand the origins and the parameters of … mental adaptations" (Campbell, 2002, p 20). EP claims that adaptations to the EEA have not disappeared during the last centuries or millennia although our environment has changed dramatically. In fact, some adaptations that helped our ancestors in the EEA may be bad for people living today, e.g. stimulation of the dopaminergic reward pathways in the brain. In the EEA, such a reward system was useful in helping the ancestors to keep up their appetite, but can now make some of us prone to develop, for example, an addiction to drugs. Also the opposite exists; adaptations may explain behaviours they were not originally designed for, e.g. our ancestor's fascination of rivalry, male-male competition and demonstration of male strength and agility can be connected to our fascination with sports today (Campbell, 2002).

Evolutionary psychologists state that humans have lived 99 per cent of their existence in hunter-gatherer societies (Campbell, 2002), so our adaptations should be traceable back to that time. In hunter-gatherer societies, men were primarily hunters and women gatherers, and

some evolutionary psychologists claim that this may have resulted in some of the sex differences in psychological mechanisms, like spatial ability, that we see today. Other evolutionary psychologists claim that depending on which sex had the largest range, males and females developed different spatial abilities (Gaulin & Fitzgerald, 1986).

Spatial ability is one of the most studied sex differences, and the results implicate that it is also one of the largest and most reliably occurring differences (New, Krasnow, Truxaw & Gaulin, 2007). Easily put, it is the ability to mentally see and manipulate objects or larger images or areas. A number of competencies are crammed under the concept ‘spatial ability’ but what is important is that they are related to the visual-spatial domain (Gaulin & Fitzgerald, 1986). Spatial ability includes e.g. spatial perception, mental rotation, spatial visualization, spatial memory and navigation skills.

This essay sets out to describe the differences in male and female spatial abilities, and offers biological as well as evolutionary explanations to why they exist. Some of the most studied spatial abilities and how they can be tested will be described next. Then sex differences will be described in a few of them and, after that, the biological and evolutionary explanations. The largest and most influential evolutionary theories will be described and discussed in this essay. They set out to elucidate why differences in spatial abilities of men and women may have evolved. Though there are differences between men and women, on average, in spatial abilities, this essay will not involve questions of equality between the sexes since that is a completely different topic. Also, in no sense does this essay impose that any sex is superior the other.

Spatial Abilities

To help the reader to further understand what spatial abilities are all about, the main ones will be introduced next and some examples of tasks that can be used to test them will be provided. Spatial perception is the ability to make judgements on orientation of lines despite

distracting information, and it can be tested, for instance, by drawing a water-line in a tilted glass (Gur, Levin, Irani, Panyavin, Thomson, & Platek, 2007). Mental rotation is pretty much what it sounds like; to mentally rotate objects or figures in space and to be able to mentally see them from different angles. Spatial visualization is the ability to manipulate spatial information using an analytic strategy. The task can be, for example, to see an embedded figure in a larger picture. Spatial memory (some researchers include object-location memory as a sub-category of spatial memory) is what we use, for instance, when playing the common children's game of Memory (McBurney, Gaulin, Devineni & Adams, 1997). Navigation skills involve, among others, being led to a place and then finding the same or the shortest way back, or keeping track of where the starting point is located (Silverman, Choi, Mackewn, Fisher, Moro & Olshansky, 2000).

There are probably more spatial abilities than those mentioned and certainly more ways of testing them. For example, a task to aim projectiles at static or moving points (Gur et al., 2007), a skill that hunters must practice. Using the term spatial ability, I hence forth refer to one or several of these above mentioned skills. However, as some spatial abilities are more researched and show larger sex differences than others, the focus will be on those with most empirical evidence and relevance to this essay. These are: mental rotation, navigation skills and object-location memory.

Mental Rotation

Mental rotation includes a great deal of visualization; to hold in mind a 3D representation of an object and then be able to see it from various angles (Silverman et al., 2000). "From a purely perceptual standpoint, the process of mental rotations is equivalent to walking around the object" (Silverman et al., 2000, p. 205). Mental rotation is a spatial ability that men generally are better at than women (e.g., Buss, 2007). Silverman, Choi and Peters

(2007) made a study across 40 countries and seven ethnic groups all around the world, and in each of them men scored significantly better than women at 3D mental rotation tasks.

Navigational Skills

Navigation skills are closely related to mental rotation skills (Silverman et al., 2000). The ability to have a mental representation of the environment helps in getting to a location quickly or back to the starting point. Men are generally better at navigating than women, though in navigation tasks the sexes tend to use different strategies (Buss, 2007). While men tend to use more abstract and Euclidian terms (north, south, west and east), for example, when giving directions, women use more concrete landmarks such as trees or specific buildings.

Object-Location Memory

Jokes are often made about how men cannot find things around the house. Keys, wallet, pens or even the butter in the fridge can periodically mystically disappear, and men have to ask their female partner where the missing item is located. The study across 40 countries by Silverman et al. (2007) suggested that there is most likely a universal difference between men and women in object-location memory; there was a significant difference in all seven ethnic groups, and in 35 of the 40 countries. Women are more perceptive regarding objects in their environment, a trait that emerges in puberty when hormonal influences affect females and males in different ways (Silverman & Eals, 1992). So while men often excel in other spatial abilities, women primarily have better object-location memory.

In a study by New et al. (2007), people were led through a farmers' market, stopping by some food stalls to taste different foods, for instance, different types of vegetables, fruits, berries and so on. Then the subjects were taken to the centre of the market place, where they were asked to point out the approximate locations of the foods they had tasted. Notice that this way of pointing to locations favours men's spatial navigation abilities. Despite this, women

were more accurate in pointing towards the specific food items. New et al. (2007) also found that both men and women pointed more accurately towards the foods more rich in calories, such as olive oil, almonds, avocados and honey.

Biological Explanations for Differences in Spatial Abilities

Several differences between men and women have been found that could help explain the differences in spatial ability. Brain morphology, hormones and genes may all contribute (Gur et al., 2007; Puts, Gaulin & Breedlove, 2007). Next, I will present these biological explanations for sex differences in spatial abilities.

Brain Morphology

Male and female brains are not exactly similar. They differ not only in size but also in organization (Gur et al., 2007). Improvements in functional neuroimaging technology have made possible more exact studies of the brain areas connected to spatial abilities (Gur et al., 2007). Several brain areas are involved in solving spatial problems, and they are not only functionally but also neurally distinct (New et al., 2007). Each brain area has its own expertise and some of these expertises are shared by both men and women while others are not (New et al., 2007).

One brain area related to spatial ability is the hippocampus and it is often larger in the sex with superior spatial ability (Puts et al., 2007), which in humans is males. Men are also more dependent on the hippocampus in their spatial processing, while women additionally are more reliant on the prefrontal cortex and perhaps also the parietal cortex (Puts et al., 2007). One explanation for why women have better object-location memory and excel only in this spatial skill could therefore be that it requires multiple cognitive processes (Puts et al., 2007).

The prefrontal cortex may be connected to the female preference of using landmarks in navigation (Puts et al., 2007), and “there are genuine sex differences in brain activation

patterns during mental rotation activities even when performances are similar" (Gur et al., 2007, p. 394). Remember though that the differences in the brain related to the difference in spatial ability do not have to be as 'bulky' as they have been described here, but much more subtle, as differences in cell soma size, neuron density or dendritic arborisation (Puts et al., 2007). Further, in the end little is known about the sex differences in the brain, why and how they occur and their connection(s) to spatial ability (Puts et al., 2007).

Hormones and Genes

Hormonal influences on spatial ability have been studied in people with disorders that disrupt the hormonal balance (Gur et al., 2007), for example, congenital adrenal hyperplasia, idiopathic hypogonadotropic hypogonadism, Turner syndrome, and complete androgen insensitivity syndrome (Puts et al., 2007). Simply put, these disorders render the affected females unusually high testosterone levels or the affected males remarkably low levels. Studies have led to the theory that testosterone improves (male types of) spatial abilities up to an optimal level (Gur et al., 2007), while testosterone levels higher than that seem to decrease performance in spatial tasks. In contrast, the female hormone oestrogen seems to impede the typically male spatial abilities (Puts et al., 2007). The differences in spatial ability between males and females seem to become more distinct after puberty (Silverman & Eals, 1992), a finding also supporting the idea of hormonal influence on spatial abilities.

Regardless, although the hormonal evidence for spatial abilities is strong, a directly causal relationship between hormone levels and performance in spatial tasks would be easier to find in within-subject studies where subjects' hormone levels are manipulated (Puts et al., 2007). Although it is not possible to design such a study due to ethical issues, some studies have been made before and after testosterone or oestrogen treatment in transsexuals (Puts et al, 2007). In the studies described in Puts et al. (2007), there were none that could prove on significant changes in spatial ability after hormone treatment, whether it was testosterone or

oestrogen, denying hormonal influence on spatial ability. Nevertheless, the results may have another interpretation: the influence of testosterone and oestrogen on brain morphology and function may be largest during the foetal period, providing the developing foetus tendencies toward either “male” or “female” types of spatial abilities.

There are also some theories regarding the role of genetic make-up in spatial ability, but according to Gur et al. (2007), none of them satisfactorily explain why there are differences in the genetic make-up between men and women in the first place. One thing worth mentioning, however, is that the Y-chromosome that men have (and some females with complete androgen insensitivity syndrome [Puts et al., 2007]) may have something to do with the heredity of good spatial abilities in men (Gur et al., 2007). Again, the hormonal influences related to Y-chromosome would start to take place in the womb, and affect the developing brain.

It has been suggested that performance in spatial tasks improves with practice (Gur et al., 2007), perhaps readers have noticed it after playing Memory repeatedly. It has also been suggested that culture has an influence on sex differences in spatial ability (Puts et al., 2007). If this was the case, then the levels of sex differences in spatial ability would vary across cultures. Alternatively, the magnitude of the difference would change over a few generations, which is enough time for the culture, but not for the gene pool, to change (Puts et al., 2007).

Theories Regarding Spatial Ability in Evolutionary Psychology

Evolutionary psychological theories try to go beyond the specific mechanisms of the brain, hormones, genes and culture, and offer explanations as to how the differences between men and women in brain anatomy and function, as well as hormonal effects, came to exist in the first place (Silverman & Eals, 1992).

> “The tenet of evolutionary theory is that form follows function, in regard to anatomical, physiological, behavioural, and cognitive variables. If spatial sex

> differences were selected for because they maximized the effectiveness of division of labour, then it would follow that sex differences in lateralization emerged as a consequence – the psychophysiological mechanism to which the selection pressures gave rise" (Silverman & Eals, 1992, p. 547).

There are several evolutionary theories about spatial differences in men and women, but only those with the most influence, (those most accepted and have the highest rates of referencing) will be brought up. Those are the male range theory, the hunter-gatherer theory and the twofold selection theory.

The Male Range Theory

In 1986, Gaulin and Fitzgerald put forth the practically first evolutionary hypothesis attempting to explain sex differences. In their article, they focused on differences in spatial ability, hypothesizing that they "are a consequence of sexual selection for particular ranging patterns" (Gaulin & Fitzgerald, 1986, p. 74). They assumed a relationship between ranging patterns, that is, individuals' movements, and mating system. They predicted sex differences in spatial ability in polygamous species where one sex moves over large areas and the other stays relatively close to the nest. In monogamous species, on the other hand, in which both sexes have similar ranges, there would be no difference.

To test their hypothesis, Gaulin and Fitzgerald (1986) studied one group of meadow voles, which are polygamous, and one group of pine voles, which are monogamous. Data regarding the home ranges of both species was collected in the wild, and later in the laboratory, their spatial ability was tested in a maze. "In the promiscuous meadow vole, males both range more widely than females and perform better on the maze task; in the monogamous pine vole, no sex difference is observed in either ranging pattern or spatial ability" (Gaulin & Fitzgerald, 1986, p. 82). Cautiously, they draw the conclusion that their

hypothesis is consistent with the facts that humans are generally polygamous, and men have, on average, superior spatial abilities.

The Hunter-Gatherer Theory

Silverman and Eals (1992) have created a theory that focuses on humans. They believe that "the critical factor in selection for spatial dimorphism in humans was sexual division of labour between hunting and gathering during hominid evolution" (Silverman & Eals, 1992, p. 543). Hunting; tracking, killing animals and bringing them back to the habitat requires spatial abilities that men are generally better at, such as mental rotation and Euclidean navigation. In contrast, foraging includes finding immobile food plants and having a good memory for objects and locations to be able to find the same food resource again and again, season after season. This requires the primarily female spatial abilities of good object-location memory, (landmark) navigation and preferably good peripheral perception and incidental memory for objects and their locations.

There may also be a connection between females' spatial skills and their verbal superiority, specifically their ability to remember objects' names (Silverman & Eals, 1992). These abilities are suggested to have evolved alongside each other, also affecting the more heterogeneous hemispheric functions of women.

The Twofold Selection Theory

Ecuyer-Dab and Robert (2004) have come up with a theory based on the empirical and theoretical findings of both Gaulin's and Fitzgerald's and Silverman's and Eals's theories. They suggest that the typically male spatial abilities may have been selected for due to competition between males over mates, "involving extensive ranging and agonistic displays" (Ecuyer-Dab & Robert, 2004, p. 221). The female superior spatial memory primarily evolved to help them and their offspring keep safe from predators. This involves the ability to learn

and recall details of their immediate surroundings, to notice predators close-by and find hiding places or escape routes fast (Silverman et al, 2007). This theory can be applied on humans as well as on other species (Ecuyer-Dab & Robert, 2004).

Discussion

Strengths and Weaknesses of the Theories

What an evolutionary hypothesis must explain, according to Puts et al. (2007), can also be applied to biological hypotheses. Puts et al. (2007) state that a satisfactory theory must explain why men are better at most spatial abilities and why women have better object-location memory. A worthy theory should also explain the same features in other mammals. Proponents of biological theories and proponents of evolutionary theories may debate what actually causes the sex differences in spatial ability (Gaulin & Fitzgerald, 1986). The theories of the greatest importance might be created, though, if these theories are seen as complementary to each other, rather than competitive (see also Gur et al., 2007).

Theories based purely on biological mechanisms may never fully explain sex differences in spatial ability, certainly not why they exist. The plasticity of the brain areas underlying spatial ability and the influence hormonal fluctuations has on them must have some benefit for humans (Puts et al., 2007). Spatial demands may have, in the EEA, changed for example seasonally or with pregnancy (Puts et al., 2007).

Evolutionary principles, for example, that males can reproduce more rapidly whereas females first are pregnant and then invest much in the child(ren), providing, for instance, food and protection (Puts et al., 2007), are common to all these theories. This means that males compete more for the possibility of mating. Therefore, “selection favours competitive traits more in males than in females” (Puts et al., 2007, p. 337).

Gaulin's and Fitzgerald's theory says that men have good spatial ability because our male ancestors travelled long range to meet females. Why would they need good spatial ability for this? After all, people in the EEA lived in small, tight groups, and most likely mated with members of their own group. On the other hand, it seems like the other individuals in the group would have been primarily kin (Gaulin & McBurney, 2004). Then the question is whether our male ancestors needed spatial ability to find their way back to their group or to the women living in other near-by groups? The same question can be applied to Ecuyer-Dab's and Robert's theory. They say almost the same thing as Gaulin and Fitzgerald regarding the male spatial ability, but emphasize the competition between males over mates rather than just the desire to reproduce. Does this imply that male ancestors also needed to know where the other men were in relation to themselves? Silverman and Eals on the other hand, say that our male ancestors travelled long range to hunt, and therefore needed good spatial ability to find their way back. They have not considered mating at all.

To sum up, the hunter-gatherer theory dismisses the importance of mating, and the mating hypotheses overlook hunting. Male spatial ability could have evolved to help in both activities. I also miss an approximate time of when the sex differences arose, and how our ancestors' brains might have looked like before that time. Or have male and female brains always been different? If not, what caused the differences to emerge?

Gaulin's and Fitzgerald's result also has an alternative explanation (Silverman and Eals, 1992) that tends to weaken their theory. Species in which males locate and defend females, males have greater dispersal and superior spatial ability. Species in which males hold territories and try to attract females into them have greater female dispersal and female superiority in spatial ability. Species with neither of these tendencies would show no dispersal difference and no sex difference in spatial ability.

From what I have read, Silverman's and Eals's theory seems to have had the largest impact, especially with their finding that women have better object-location memory. It may not extend very well across species (Silverman and Eals, 1992), not fulfilling all of Puts et al.'s (2007) requirements. On the other hand, EP sets out to explain only the human evolution. It is possible that other species have developed similar sex differences due to another cause.

Silverman's and Eals's theory also makes predictions that are easier to test empirically. The Ecuyer-Dab and Robert theory was published in 2004 and therefore, objective results supporting or opposing the theory might not have been published yet. They have produced a good, plausible explanation, but their predictions do not seem easy to test. Especially not their hypothesis that women find hiding places easier than men, and that they are better at noticing predators. Since primarily men hunted in the EEA, we can be sure about that they would have been very good at noticing predators, be silent and stay hidden until they could strike their prey.

What could lead to one theory standing and one falling is testing lions (Silverman & Eals, 1992). They are polygamous, according to which Gaulin and Fitzgerald predict higher male spatial ability, but females do most of the hunting, according to which Silverman and Eals predict higher female spatial ability. But perhaps it is a battle that no one can win; different theories may always explain different things to varying degrees.

Future Empirical Experiments

Differences between men and women are often described in linear terms (Silverman et al., 2007). Typically male spatial abilities are then regarded as being of higher value than female spatial abilities. I have come across this implication many times, especially in texts about navigation. Researchers should be cautious saying that one spatial ability or strategy is superior another. It could very well be so that, for example, test methods offer benefits to one sex. Many experiments are done in a laboratory, while performing experiments in the real

world might give more reliable and realistic results, especially in navigating. Surely, there were no laboratories, pencil-and-paper or computer tasks in the EEA. In the New et al. (2007) study, for example, women defied the method benefiting men and excelled in pointing towards the foods' locations.

Studies made across cultures or generations to see if culture or environment has an influence on sex differences in spatial ability would be interesting. But I do not encourage a nature-nurture debate. Now that we have the ability to travel longer distances faster and GPS is a very popular device for navigating, will the human spatial ability change in any way? Will it be impaired, improved or changed at all?

Silverman and Eals relate object-location memory in women with their verbal skills. It would be interesting to see if other spatial skills are related to other cognitive skills. These could be, for instance, different visual abilities and attention. Perhaps a sense for sculpturing, painting and crafting can be connected to mental rotation.

Conclusion

Clearly there are differences in spatial abilities between men and women. Both biological and evolutionary psychological theories offer explanations as to how the differences develop or why they exist. Regardless, thus far none of the explanations stands alone: therefore biological and evolutionary explanations may together be the best tool to help solve the questions of why the differences exist and how they developed in our species.

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