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The Interplay of Sex and Learning Method Selection: A Study on the Reciprocal Influence on Cognitive Abilities

Hiu Si Lam[1,a,*]

[1]*Faculty of Medicine, Nursing and Health Sciences, Monash University, Clayton, VIC 3168, Australia*
a. Hlam0037@student.monash.edu
**corresponding author*

Abstract: As the society continues to evolve, the demand for top-notch education has grown in tandem. Understanding the interplay of sex, learning method selection, and cognitive abilities in cognitive development is crucial for optimizing educational strategies and outcomes. This study aimed to investigate the relationship among sex, different learning methods, and cognitive abilities across different cognitive domains. A diverse body of literature was systematically examined, which includes studies employing various cognitive tests and learning method assessments in different sex and age cohort. As predicted, results revealed a significant interaction between sex and learning method selections in cognitive abilities. Females have the advantage of the influences of hormones and timing of cognitive maturation in cognitive abilities, leading to better performance in verbal memory tasks, more efficient responding, and better inhibitory control. As males perform best in competitive learning environments and females in cooperative environments, implying the interaction between sex and cognition in learning method selections. The findings of this review highlighted the complex interplay between sex, learning methods, and cognitive abilities, underscoring the need to take individual strengths and sex differences into account when selecting learning methods. Insights from this study have implications for educational practices and policymaking, suggesting the potential for a more personalized learning approach to enhance cognitive abilities and academic performance. Further research direction and limitations are also discussed.

Keywords: cognitive abilities, sex differences, learning methods, cognitive development, educational outcome

1. Introduction

When understanding how an individual thinks about and understand the world around them, it is vital to investigate their cognitive abilities. Studies on cognitive abilities were highly influenced by Jean Piaget's innovative work delineated cognitive growth as a stage-like progression [1]. Piaget's cognitive developmental stage theory suggested that individuals understand the world through changes in different cognitive processes and abilities [2]; later studies found that several factors, such as biological and socioeconomic factors, could affect cognitive development [3]. The current article focuses on the interplay of sex and learning method selection in cognitive abilities. The critical assumption is that females, due to early maturation of certain cognitive abilities, might perform better

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in areas such as verbal tasks, while males may excel in spatial cognition due to differences in brain development.

Moreover, learning methods with less control or help from others will improve cognition. Furthermore, the more cognitively mature an individual is, the more they would incline to learning methods with more self-autonomy. This topic is relevant to the educational field, where teachers are usually given more control over younger students [1,4].

This article reviewed literature showing that sex and learning methods influence cognitive abilities, thus underscoring that those cognitive abilities are influenced by various interacting factors and the need to tailor learning methods based on a more complex understanding of the individual to maximize effectiveness.

2. Sex Differences in Cognitive Abilities

According to Piaget's cognitive developmental theory, individual usually experience the earliest stage of cognitive development - sensory-motor stage - from birth to 2 years of age, acquiring knowledge through sensory experiences and manipulating objects, including basic reflexes, senses, and motor responses [1]. Following with the pre-operational stage, which usually occurs from 2 to 7 years of age, with the emergence of language is one of the major hallmarks [1]. Individuals started to become more adept at using logic at 7 to 11 years of age when entering the concrete operational stage [1]. Lastly, individual became competent to see more than one potential solutions to problems and think in a more scientific way [1]. But highlighted individuals' difference might occur in age when conquering the 4 stages [1]. However, Simmonds et al. [3] used a 3T MR Siemens MAGNETOM Allegra scanner to scan 128 typically developing individuals (age 8-29, M=14.9) five times each and found significant sex differences in the timing of white matter (WM) maturation, which WM have a reciprocal influence on cognitive development [3]. The findings illustrate that males experience an ongoing progression of white matter (WM) development from childhood through the onset of adulthood. In contrast, females predominantly exhibit this growth phase during their mid-adolescent years [3]. Furthermore, the study uncovered that WM continued to mature with gains in cognitive abilities; contrary, the timing of WM growth can forecast cognitive performance; specifically, earlier WM growth was associated with quicker and more effective processing and improved ability to control impulses [3].

Similarly, other research found that males often outperform females in visuospatial tasks, while females outperform males in verbal memory tasks [5-7]. Results suggested that sex differences in cognitive abilities, such as visuospatial, might be driven by distinct patterns of brain activation in males and females, supported by the finding that males showed predominant parietal cortex activation. In contrast, females showed inferior frontal activation [7]. A study by Ingalhalikar et al. found that male brains show higher connectivity with hemispheres, suggesting an information-processing performance in spatial tasks. In contrast, female brains show higher connectivity between the left and right hemispheres of the brain, which might contribute to their proficiency in verbal tasks [8]. The study also suggested hormones as another vital role in influencing cognitive abilities; estrogens and progesterone affect an individual's performance in spatial tasks. The activation of various brain regions is influenced by the fluctuating levels of estrogens and progesterone throughout distinct phases of the menstrual cycle [7]. For example, women often exhibit superior performance in spatial tasks when the levels of estradiol or progesterone are lower rather than higher [7].

Importantly, sex differences are also found in the rate of cognitive decline, with men exhibiting a steeper decline in cognitive function than women, particularly in the realms of attention and memory [7]. These findings suggested there is a reciprocal influence between sex differences and cognitive abilities throughout the whole lifespan, supporting the hypothesis that females generally have natural advantages in early cognitive maturation leading to better cognitive ability in some cognitive domains.

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3. Learning Method Selection and Cognitive Abilities

Being educated for a certain number of years is not only compulsory in most countries, but learning is also a natural ability to be born with. In the 1960s, psychologists believed that learning was always the result of classical and operant conditioning, in which individuals learn by associating events, specifically by pairing two stimuli or pairing a behaviour to a result. However, Bandura developed a Bobo Doll experience – a set of controversial studies involving preschool children, adult models, and a stand-up punch doll to prove that children can learn from mere observation [9]. In Bandura's experiment, preschool children were shown in real life a video or a cartoon animation of an adult model aggressively punching a Bobo Doll, an adult was then deliberately frustrated the child by taking away the toys the child played with [9]. Afterwards, the frustrated child was observed to determine whether they would copy the adult's behaviour. With the experiment result, Bandura concluded that learning could occur by observing a behaviour and the consequences of such; notably, the result from the Bobo Doll experiment highlighted that children imitate others regardless of where they have seen the behaviour [9]. Bandura and his co-worker also suggested that learning is a reciprocal determinism process in which cognition, behaviour, and environment mutually influence each other [9].

Like Bandura's social learning theory, reciprocal relationships between cognitive abilities and learning are also supported by other studies. A study by Diamond & Lee examined a few learning methods that can improve executive functions – a critical cognitive process that regulates thought and action – in children aged 4-12 and were found to be able to enhance learning [10]. The research posits that executive functions, encompassing elements such as inhibitory control, working memory, and cognitive flexibility, play an indispensable role in facilitating learning. It enables learners to focus on task-relevant information, ignore distractions, hold and manipulate information in minds, and switch between tasks or mental sets [10]. Examining a few interventions shows that computerized training programs can improve working memory, and martial arts and mindfulness training can help improve inhibitory control and cognitive flexibility [10]. At the same time, aerobic exercise and student-centred learning enhanced executive function [10]. These results suggested that learning methods might be more effective when actively engaging learners and giving them control over their learning, as they improved the child's executive function. Similarly, Dunlosky et al. also found that consistent use of some of the learning methods that students most apply could enhance cognitive abilities [11]. To elaborate, high-utility techniques such as distributed practice, which involves spacing study sessions over time, may augment abilities in self-regulation, time-management, and planning through regular engagement [11]. The technique of practice testing, requiring the abilities of recall and retrieval, could strengthen these cognitive skills through habitual self-testing or by undertaking practice exams [11]. Elaborative interrogation could potentially enhance comprehension and reasoning abilities by facilitating the process of elucidating why a particular fact holds true [11]. The strategy of self-explanation could foster analytical and logical reasoning skills by detailing the connections between new information and existing knowledge, or by outlining the steps involved in problem-solving [11]. Lastly, interleaved practice, which involves a mixture of various types of problems within one study session, could boost cognitive flexibility and adaptability [11].

Although these learning methods has shown to enhance learners' cognitive abilities, the effectiveness of each learning method might fluctuate depending on the strength of the individual's cognitive abilities, influencing the choice of learning method. For example, suppose an individual selects constructive & inquiry-based methods, which require learners to process information and learn simultaneously. In that case, the method might overload the working memory if the learners do not have enough working memory capacity, consequently hindering learning [12]. However, although Kirchner et al. argued that learning methods with minimal guidance, such as constructive & inquiry-

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based methods, are often less effective because they ignore the cognitive architecture that constitutes human cognition, but also suggested that guidance can be gradually faded as learners gain more experience, as the cognitive structures stored in long-term memory can be used to reduce the working memory load [12]. Furthermore, Bjork et al. suggested that learners with higher cognitive abilities are more likely to select learning methods, such as self-explanation, elaborative interrogation, and interleaved practice which require higher cognitive effort, as learners with high cognitive abilities are more likely to use these methods successfully and effectively [13].

Conversely, learners with lower cognitive abilities might find these methods too challenging and not select them [13]. Indicating that cognitive abilities can influence learning method selections and the belief or perception that cognitive abilities play a significant role during selection. These findings support the assumption that learning methods with less control or help from others will improve cognitive abilities, and the more cognitively mature an individual is, the more they would incline to learning methods with more self-autonomy.

4. Sex Differences, Learning Method Selection, and Cognitive Ability

While sex differences and learning method selection influence cognitive abilities through cognitive development, they also play a role in older age. Some reach suggested that females have an advantage over males in maintaining cognitive abilities with age due to the higher estrogen receptor alpha gene (ESR1) level. However, results from examining the role of ESR1 and cognitive outcomes in females also suggested that the loss of estrogen's protective effect after menopause could contribute to increasing risks of cognitive decline in females [14]. Similarly, Halpern suggested that education is a form of cognitive reserve, as it can buffer against cognitive decline. These findings further suggest that females who chose an effective learning method might be the group with the advantages of the latest cognitive decline time [15].

Furthermore, with the well-studied sex difference in cognitive abilities, for example, it is frequently observed that males excel in tasks requiring visuospatial skills compared to females [5-7]. Conversely, when it comes to verbal memory tasks, females tend to surpass their male counterparts. [5-7]; the selection of learning methods should be included. As males learn best in a competitive learning environment, while females often perform best under cooperative learning conditions [16], a further assumption can be made that the interaction of sex, learning methods, and cognitive abilities could predict a learner's academic performance, emphasizing the need to take sex and cognitive abilities into account when selecting learning methods.

5. Discussion

This article aimed to provide insight into the complex reciprocal relationship between sex, learning method selections, and cognitive abilities. The review revealed significant differences in cognitive abilities between males and females, shaping how individuals process, retain, and use information. As research demonstrated, biological sex substantially impacts cognitive development and, subsequently, learning preferences, thereby leading to varying strengths and weaknesses in cognitive abilities. Regarding the assumption, the differences in cognitive abilities between sex were found to be significant, aligning with the findings that the timing of WM maturation differs between males and females [3], suggesting that sex differences may extend beyond physiological development to cognitive abilities, including visuospatial and verbal memory tasks [5-7]. Nevertheless, converging societal expectations and cultural indoctrination is crucial in determining the perceived cognitive differences between sexes [17]. In addition, it is essential to note that sex differences in cognitive functions vary depending on the type of skill assessed [5], these differences, which appear to be related to the activation of different brain regions, indicate that each cognitive domain requires a

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different neural network [7]. However, not only did the pattern that males outperformed females in the spatial test has been changing [5], but the research also found that sex differences generally do not present in children aged under ten [7], highlighting the fluidity of these abilities.

Moreover, further research in cognitive development has unveiled distinct developmental paths for males and females, each exhibiting unique cognitive strength. Such differences influence individuals' learning method selections, with males generally favouring competitive environments while females thrive in cooperative settings [16]. However, the rapid advancement of digital technology has considerably altered the cognitive development landscape, prompting an evaluation of its influence on cognitive abilities and learning preferences [18]. Nevertheless, the effectiveness of such learning methods can fluctuate based on the individual's cognitive strength [10]. However, the effectiveness of learning methods can vary based on the individual's cognitive strengths [12], allowing those with heightened cognitive abilities to opt for more demanding, self-regulating learning methods, while those with lower cognitive abilities find success with guided techniques. Underlining the importance of personalized educational strategies in facilitating effective learning. Despite this, educational institutions seldom assess students' learning skills and practices or offer guidance on how to learn [14]. As such, it became pivotal for learners to understand their cognitive functioning and control their learning activities effectively.

6. Limitation

This article offers insightful findings on sex, learning methods, and cognitive abilities; however, certain limitations must be acknowledged. This article was restricted to English language, peer-reviewed journals, potentially leading to language and publication bias. The lack of standardization in cognitive tests and learning method assessments across the studies might have affected result comparability. This article primarily targeted specific age groups, which may limit the applicability of findings to other age cohorts, such as younger children or older adults. Moreover, the potential influence of cultural, socioeconomic, and environmental factors on cognitive abilities and learning was not explored. Future research should rectify these limitations to refine our understanding of these intricate relationships further.

7. Conclusions

To conclude, the findings align with past studies suggesting cognitive development differences are influenced by various factors, including biological and socioeconomic. This article emphasized the need for custom-tailed educational strategies, indicating the potential to enhance educational outcomes. A more nuanced understanding of these dynamics could pave the way for more personalized and effective educational methods, augmenting cognitive abilities and academic performance.

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