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Effects of cognitive style and gender differences on heuristic problem-solving ability in young adults

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ABSTRACT

Humans use heuristic problem-solving ability when they want to solve complex problems very quickly. The present study investigated the effects of cognitive style and gender difference on heuristic problem-solving ability of young adults. Participants (N = 96) were 300-level (undergraduate) students of University of Nigeria, Nsukka, who were attending cognitive psychology (PSY 102) class. There were 52 (54.17%) male and 44 (45.83%) female students. Their ages ranged between 19 – 26 years (Mage = 20.56; SD = 4.72). More than half of them (n = 51, 53.13%) utilized the field dependent cognitive style while 45 (46.88%) had the field independent cognitive style. Participants worked individually on the Tower of Hanoi problem. F-statistics showed that participants using the field independent cognitive style moved more disks than participants possessing the field dependent cognitive style. Male participants performed better on the task than female participants. A significant interaction effect of cognitive style and gender was found, indicating that neither cognitive style nor gender had a simple independent effect on heuristic problem-solving ability. Implications of the findings for education and learning were highlighted.

Introduction

The ability to solve problems and solving them quickly is a core component of human existence. Reisberg (2007) argued that two primary approaches to the study of complex problem solving, which have different emphases, are algorithm and heuristics. Algorithm is a step-by-step procedure that checks every available option. Algorithm guarantees that a problem solver would eventually find the solution, but it often takes too much time to be practical. Heuristics on the other hand allows the individual to consider only a subset of available options instead of searching the entire problem space. Thus, heuristics are quicker, but it involves an element of risk: it may or may not lead to correct solution. Simon and Newell (1972) argued that several heuristic problem-solving are revealed when people solve the Tower of Hanoi problem. The Tower of Hanoi problem is a game; game playing is a special kind of problem solving in which the problem is to find a winning strategy or the best current move (Garnham, 1988). In the Tower of Hanoi problem, a participant transfers a number of disks from the left to the right pole. The disks must be moved one at a time and the individual must never place a larger disk on top of a smaller one. Some authors (Simon & Newell, 1972; Holyoak, 1995) believed that in trying to solve this problem, people often rely on a particularly important general heuristic known as means-ends analysis (MEA). That is, to break down main goal into sub-goals, each of which has to be solved before the main goal can be reached.

Cognitive style refers to an individual's habitual mode of problem solving, thinking, perceiving and remembering (Riding & Cheema, 1995). It determines whether an individual would think about problems in terms of deep structure or would focus on the surface form of the problem. Mayer and Massa (2003) defined cognitive style as "the ways that people process and represent information" (p. 833). Also, Riding and Rayner (1988) described it as fairly fixed characteristics of an individual that are static and are relatively in-built features of the individual. There are several kinds of cognitive style, but the field dependence-independence cognitive style (Witkin, Oltman, Raskin, & Karp, 1971) is the most popular, and perhaps, the most studied in literature. The field dependence-independence cognitive style theory (Wapner, 1986) maintained that field dependence versus field independence cognitive style constitutes a significant source of differences in ways people think and solve problems. The theory revealed that people who possess the field independent cognitive style tend to notice details and have greater analytical and differentiating ability than people possessing the field dependent cognitive style. Individuals with the field independent cognitive style are more analytical and relates to internal frame of reference, while those possessing the field dependent cognitive style are socially inclined and are given to external frames of reference (Fritz, 1992).

Several studies (Dougla & Riding, 2007; Graff, 2003; Li, Dong, & Gong, 2009; Mefoh & Ezeh, 2016; Tinajero & Paramo, 1997) show that the field dependence-independence cognitive style constitutes important aspects of individual differences among students with respect to the way they acquire and process problem information. Individuals with different cognitive style pay attention to different aspects of information;

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they encode, store, and recall information differently and also think and comprehend in different ways that correspond to their respective cognitive style. Mefoh, Nwoke, Chukwuorji and Chijioke (2017) observed that adolescents who possess the field independent cognitive style performed better on a puzzle box problem (PBP) than their field dependent counterparts. Many other studies have examined the field dependence-independence cognitive style on many performance tasks and found that field dependence-independence cognitive style was a significant source of variation in students' overall performance (Douglas & Riding, 2007; Handal & Herrington, 2004; Mefoh & Ezeh, 2016; Mefoh et al., 2017; Tinajero & Paramo, 1997). Mefoh and Ezeh (2017) argue that "there seems to be, from several sources, a consensus that the field independent cognitive style, because it uses an active reasoning pattern, tends to be more successful in processing information" (p. 45). The field dependence-independence cognitive style is to associate to gender-based demographic factor. According to Fritz (1992), "females are more likely to have a social or field independent cognitive style, whereas males more often have analytical or field independent cognitive style" (Fritz, 1992, p. 3).

Do men differ from women in heuristics problem-solving ability? In a study that investigated gender differences between male and female adolescents' problem-solving skill in tracing and demarcating target words on a puzzle box, Mefoh et al. (2017) found that male adolescents solved more puzzle problem tasks than female adolescents. The strongest evidence of gender gap in cognitive abilities between men and women is on the performance of visual-spatial tasks. Men surpass women in visual-spatial tasks, which involves mentally rotating an object and estimating its horizontal and vertical dimensions (Janssen & Geiser, 2012; Kaufman, 2007). Some studies have attributed this difference to the evolutionary hypothesis (Sahlins & Service, 1960), which posited that gender-roles predispose men and women to behave in specific manners. The hypothesis argued that in most traditional societies, men's primary task is to obtain livelihood, whereas women's is to raise offspring. Thus, from early childhood, boys are permitted to stray further from home than girls, and are more likely to engage in tasks that involve spatial manipulation or judgment of moving objects.

A more plausible explanation of the difference between men and women in problem-solving heuristics ability is the biological or lateralization hypothesis (Geschwind, 1979), which states that cerebral hemispheres are process oriented. That is, the activities of prenatal testosterone slow down the development of the left hemisphere where language skills are housed, and in the process permits enhanced growth of the right hemisphere, which is associated with spatial skills. Hence, with superior right hemisphere, males perform better than female on visual-spatial tasks, while females with left hemisphere dominance excel on various language-related tasks (Halpern, 1997). The present study investigated two hypotheses. The first hypothesis proposed that participants possessing the field independent cognitive style would solve appreciably more Tower of Hanoi problem within permissible latency than participants possessing the field dependent cognitive style. This perspective is supported by both theory and data. The field dependence-independence cognitive style theory predicts that people who possess the field independent cognitive style use active reasoning patterns that spontaneously show them to be superior over individuals who utilized the field dependent cognitive style. Also, converging evidence (in data) show that people possessing the field independent cognitive style typically demonstrate higher level of achievement than people with field dependent cognitive style across puzzle, reading, mathematics and science achievement (e.g., Fritz, 1992; Mayer & Massa, 2003). The second hypothesis stated that male participants would significantly solve more Tower of Hanoi problem within the allowed duration than their female counterparts. This perspective is based on the fact that moving disks in the Tower of Hanoi problem requires spatial ability, and males performed better than females on spatial tasks.

Method

Participants

Ninety-six third-year undergraduate students of Psychology in University of Nigeria, Nsukka, who were attending cognitive psychology (PSY 302) class participated in the study. There were 52 (54.17%) male and 44 (45.83%) female students. Their ages ranged between 19 – 26 years (Mage = 20.56; SD = 4.72). Before the study got underway, written informed consent was obtained from the students. All the precautionary measures necessary for conducting research with human participants were duly adhered to, and the students were informed prior to the commencement of the study that they can withdraw from the research at any time (if they so wish).

Materials

Two materials were used in this study: the Group Embedded Figures Test (GEFT) (Witkin, Oltman, Raskin, & Karp, 1971) and Tower of Hanoi problem. The GEFT is a bipolar perceptual test that classifies individuals as possessing field dependent or field independent cognitive style. The test requires individuals to locate a simple figure when the figure is embedded within complex patterns. It consists of 25 items organized into three sections. The first section has 7 items and is used for practice. The other two sections contain 9 items each, which are scored to identify participants' cognitive style dimension. Each figure correctly located within the group embedded figures was scored 1. Scores range from 0 – 18; the GEFT score reflects the level of a participant's perceptual disembedding ability. The GEFT has satisfactory validity (r = .82, between the two major subsections) and reliability (r = .89, on test-retest over three-year period) (Witkin, et al. 1971). It has been widely used around the world. In Nigeria, GEFT has test-retest reliability and content validity indexes of .67 and .76, respectively (Mefoh & Ezeh, 2016). In the present study, 45 participants (46.88%) possessed the field independent cognitive style, while 51 (53.13%) expressed the field dependent cognitive style characteristics.

The second material used in the study was the Tower of Hanoi problem (see Figure 1). The Tower of Hanoi problem is a puzzle. It consists of three vertical rods/poles and a number of disks (or rings) of different sizes, which can slide onto any of the three rods/poles. The puzzle starts on the left pole with the disks stacked in ascending order of size (that is, the largest disk is at the bottom and the smallest one is on top). The task is to move the disks to the right pole. The middle pole is used as a stationing or working area. The disks used in the Tower of Hanoi problem can range from three to seven or even more, but four or more disks makes the problem sufficiently difficult. Five disks were used in the present study to measure heuristic problem-solving ability. Each correctly placed disk on the target pole was scored one mark. The higher the score, the better the heuristic ability. A pilot study to pre-test the procedure for the Tower of Hanoi was conducted with 24 volunteer undergraduate (200-level) students of the Department of Psychology, University of Nigeria, Nsukka. They were 15 female and 9 male students (Mage = 17.66 years, SD = 3.12). The internal consistency for this mock study yielded a Cronbach α of .73.

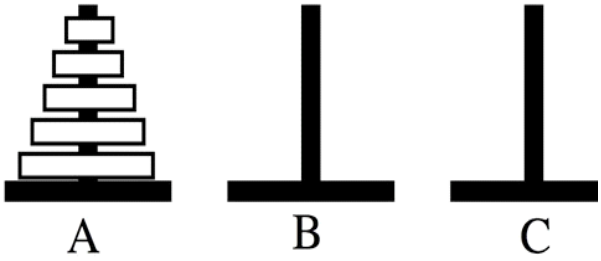

Figure 1: A representation of Tower of Hanoi task

Procedure

The Group Embedded Figures Test (GEFT) is a paper-and-pencil test. Before administering the test, the researcher used Section 1 of the test to demonstrate to participants how a figure could be traced over the lines of a complex figure. The demonstration was repeated until all the participants had sufficiently practiced the examples. Before turning over to the timed sections (i.e., Sections 2 and 3), the researcher gave out the following instruction:

> "This is a test of your ability to find a simple form when it is hidden within a complex pattern. Try to find the simple form in the complex figure and trace it in pencil directly over the lines of the complex figure. It has to be the same size, in the same proportions, and face the same direction within the complex figure as when it appeared alone."

Time allowed for completing the GEFT test was 10 minutes. All the participants completed the test inside the classroom.

The dependent measure for this study was the number of disks correctly placed on the target pole, within a latency of 120 seconds. The participants were shown demonstrations on how to solve the Tower of Hanoi problem. They were instructed that the task involves moving a pyramid of 5 disks from pole 'A' to pole 'C'. Each correctly placed disk is scored one mark; the range of scores for the dependent measure is 0 - 5.

The minimal number of moves to solve the Tower of Hanoi problem was 2N – 1, where N is the number of disks. However, the researcher deliberately displayed both appropriate and inappropriate moves to show all the different possibilities. Participants were encouraged to ask questions during the practice session if unsure of any aspect of the procedure.

The instruction given to participants reads as follow:

> "Welcome. Your task is to move the 5 disks on the left pole (pole 'A') to the right pole (pole 'C'). Use the middle pole as a stationing area. In solving this problem, you must obey these two rules: (1) The disks must be moved one at a time. (2) A disk can only be placed on a larger disk; no larger disk may be placed on top of a smaller disk. Good luck! "

Design/data analysis

The design utilized in this study was the between-subject quasi-experimental design. F-statistics was used to test the study's hypotheses.

Results

Participants' scores on the Tower of Hanoi problem were the index used for the heuristic problem-solving ability. Descriptive statistics showed that participants who used the field independent cognitive style displayed more problem-solving heuristics than participants who use the field dependent cognitive style (mean difference = .71). Also, male participants solved more Tower of Hanoi problem than their female counterparts (mean difference = .74). Skewness and kurtosis diagnostic tests were conducted to determine if the assumption of normality was violated. The values obtained ranged between -.62 and 1.33. Because obtained values were less than ±2, the distribution's normality was not violated.

Table 1: Summary of 2-way between-subject ANOVA

Variables	*SS*	*DF*	*MS*	*F*	*ES*
Cognitive Style	7.77	1	7.77	5.83*	0.27
Gender	111.93	1	11.93	8.65**	0.53
A x B	6.04	1	6.04	4.38*	0.38
Error	126.92	92	1.38		
Total	2172.00	96	22.63		
C. Total	155.33	95	1.64		

Note. *p<.05; **p<.01; ES = Effect size.

A two-way between-subject analysis of variance (ANOVA) was performed to test the hypotheses set out in the study. The test of between-subject effects in Table 1 showed that the mean score difference between participants who possessed the field independent cognitive style and others who utilized the field dependent cognitive style on heuristic problem solving was statistically different, $F(1, 92) = 5.83$, $p<.05$, ES = 0.27. Participants who used the field independent cognitive style showed superior problem-solving heuristic ability than participants who used the field dependent cognitive style. Regarding gender, the mean score difference between male and female participants on heuristic problem solving was also significant, $F(1, 92) = 8.65$, $p<.01$, ES = .53. Male participants seem to have higher heuristic problem-solving ability than female participants. There was a significant interaction effect

between cognitive style and gender (see Table 2), F(1, 92) = 4.38, p< 0.05, ES = 0.38. Given the charge that "neither of the two types of probability value [significance level and p value] directly reflect the magnitude of an effect" (APA, 2001, p.25), effect size (ES) values were calculated for each significant outcome. Cohen (1992) effect size (ES) categorization showed that ES of .27, .38 and .53 belonged to small and medium effects, respectively. These effect sizes (ES) were therefore considered valuable supplement to the information provided by the p values.

Table 2: Mean difference for male and female against field dependence-independence cognitive style.

	Gender			
Cognitive style	Male	Female	Mean difference	*N*
Field independent	5.44 (.23)	4.22 (.28)	1.22	45
Field dependent	4.36 (.24)	4.15 (.23)	.21	51
Mean difference	1.08	.07		
No. of participants	52	44		96

Note. The values inside the parenthesis represent standard error (SE)

Figure 2 showed the interaction effect of cognitive style and gender on heuristic problem solving. The figure plots the nature of performance of the gender variable on the two levels of cognitive style – field independent and field dependent cognitive style. The interaction effect showed that for participants who possessed the field independent cognitive style, males significantly solved more Tower of Hanoi problem than the females. Examination of the performance of male and female participants under the field dependent cognitive style showed that male and female participants possessing the field dependent cognitive style seem to be at par on their levels of heuristic problem-solving ability. This interaction effect demonstrated that male participants' apparent superiority over female participants on heuristic problem-solving ability

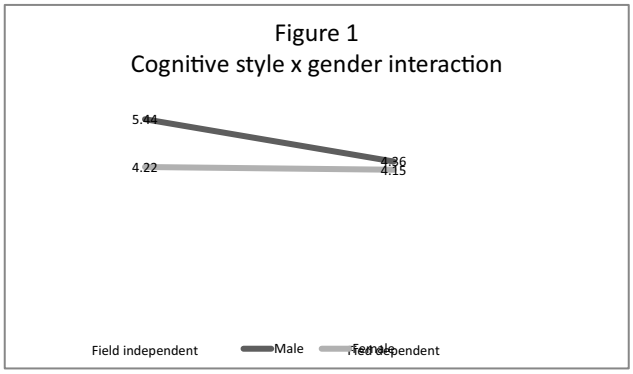

Figure 2: Graphical representation of cognitive style x gender interaction effect.

depend on whether the individuals possessed the field independent or the field dependent cognitive style.

Discussion

The present study had two objectives. The first investigated whether participants who possessed the field independent cognitive style would solve the Tower of Hanoi problem better than participants whose cognitive style was field dependent. The hypothesis that was raised to test this objective was confirmed: participants possessing the field independent cognitive style significantly solved more Tower of Hanoi problem than participants whose cognitive style were characteristically field dependent. This finding supports previous related literature (Douglas & Riding, 2007; Mefoh et al., 2017; Mefoh & Ezeh, 2016; Tinajero & Paramo, 1997), which found that individuals who use the field independent cognitive style, because they use active reasoning pattern, tend to be more efficient in processing information compared to people with the field dependent cognitive style. The difference in performance on the Tower of Hanoi problem between field independent and field dependent cognitive style should be understood in reference to the field-dependent cognitive style theory (Wapner, 1986). The theory characterized the field independent cognitive style people as people who pay attention to details and have greater analytic and differentiating abilities. These resources put people with the field independent cognitive style at advantage over people with the field dependent cognitive style on many performance tasks. The theory described the field dependent people as those who "seem to be passive in the learning context" (Fritz, 1992, p. 1).

The second objective of the study was to examine gender differences in solving the Tower of Hanoi problem. It was hypothesized that male participants would significantly solve more of the problems than the female participants. In support of this hypothesis, male participants performed significantly better than female participants on the Tower of Hanoi task. This finding resonates with many previous studies (e.g., Janssen & Geiser, 2012; Kaufman, 2007; Mefoh et al., 2017), which found male superiority over female participants on many performance tasks. Although the evolutionary theory has been used by many authors to explain similar findings (e.g., Jannssen & Geiser, 2012), this study views the lateralization hypothesis as parsimonious to understanding the gender difference in performance on the task. The lateralization hypothesis (Geschwind, 1979) predicts that males would perform better than females on visual-spatial tasks because lateralization of functions occurs quite differently in male and female brains. A huge body of evidence (e.g., Halpern, 1997; Uzzel & Homes, 2006) show that the thesis propounded by the lateralization hypothesis is well founded. The finding showing male superiority over female in different kinds of spatial task, and female advantage over male in many verbal and language-related tasks are some of the most stable facts of cognitive psychology (Reisberg, 2007).

An incidental finding in the analysis was the interaction effect observed between cognitive style and gender. The finding is instructive, as mentioned by Kantowitz, Roediger, & Elmes, (1994), that "when interaction is present, it does not make sense to discuss the effect of each independent variable separately" (p. 61). Therefore, the combined effect of cognitive style and gender imply that neither of the two factors (cognitive style and gender) had a simple independent effect on heuristic problem-solving ability. The interaction demonstrates that whether male participants would solve more Tower of Hanoi problem than female participants depend on the kind of cognitive style dimension that the participants possessed. When males possess the field independent cognitive style, they tend to have superior heuristic problem-solving ability than females.

But if the males are those who use the field dependent cognitive, both male and female participants would tend to have equal heuristic problem-solving ability.

This study has important implication for education. Studies (e.g., Li et al. 2009; Mayer & Massa, 2003) showed that the field independent cognitive style positively influence students' overall performance compared to the field dependent cognitive style. Therefore, students and other learners should be encouraged and helped to learn to use the field independent cognitive style irrespective of whether the learner is a male or a female. People with the field independent cognitive style are high achievers. The finding on interaction makes the present result more robust, as Uzzel and Homes (2006) argued that it is useful to test gender difference across other independent variables to avoid the mistake of missing to discover important finding.

One limitation of the present study was the failure of the study to hold spatial ability constant for male and female participants prior to testing them on the task. Because spatial ability provides the strongest evidence for a cognitive gender gap (Hoffman et al., 2011), the two groups – male and female, may not have been equivalent at the start of the study. This reduces the sensitivity of the findings. Future researchers therefore need to know that investigating gender differences simply by comparing male versus female behaviour against various benchmark indicators is methodologically unreliable. Researchers need to first partial out the effect of any inherent confounding variable prior to the comparison to increase the confidence of the findings.

Conclusion

People use heuristics problem-solving ability to tackle complex problems quickly, to save time. The present study investigated how cognitive style and gender influence this process. Analysis of data revealed that participants possessing the field independent cognitive style participants showed superior performance on the task compared to participants possessing the field dependent cognitive style; and male participants outperformed female participants on the task. An incidental (post hoc) finding showed a combined effect (interaction) of cognitive style and gender on heuristic problem-solving ability. In academic environments and other learning contexts, use of the field independent cognitive style should be encouraged.

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