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The relationship between students' cognitive abilities, mathematical performance and the level of Testosterone, Thyroid-Stimulating Hormone, Prolactin and Thyroxine

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Abstract

In this study researchers investigate the relationship between some specific hormones (Testosterone-Thyroid-Stimulating, Hormone-Prolactin-Thyroxine), cognitive abilities and mathematical performance. The results of this study offer a new way to conceptualize the relationship between various hormones and cognition literature for university students. According to the forty tests (twenty for males and twenty for females) performed in this survey six significant differences were found between low and high hormone groups, cognitive abilities and mathematical performance. As can be inferred from the results of this study, hormones in question have more effects on female students than male ones. Five significant differences found for female students, in contrast just one significant difference were found for male students concern to their cognitive abilities and mathematical performance.

Keywords: Math performance; Cognitive ability; Testosterone; Thyroid-Stimulating Hormone; Prolactin.

1. Introduction.

Why do some individuals perform better than others on cognitive tests and mathematical performance? Do these performance differences reflect biological influence, environmental influence, or a combination of the two? One popular explanation has focused on the role played by

individual differences in some hormones like testosterone levels. In this study researchers investigate the relationship between some specific hormones and cognitive abilities in university students:

Spatial Ability

Researchers have demonstrated that there exists a relationship between the levels of student's abilities and strategy choice and efficiency. Students of higher ability tend to solve problems by using more spatial processes, while the others try to solve mathematical problems in a more analytical way (Zhu,2007). Generally spatial abilities entail visual problems or tasks that require individuals to estimate, predict, or judge the relationships among figures or objects in different contexts (Elliot & Smith, 1983). More specifically, spatial abilities have to do with individuals' abilities to search the visual field, apprehend forms, shapes, and positions of objects as visually perceived, form mental representations of those forms, shapes, and positions, and manipulate such representations mentally (Carroll, 1993).

Some aspects of mathematics have spatial components and correlations between math and visual spatial skills have been reported (Fias & Fischer, 2005, Lachance & Mazzocco, 2006; Zhu, 2007).

Verbal Critical Reasoning

Verbal critical reasoning tests are used to find out how well someone can assess verbal logic. They are usually in the form of a passage, or passages of prose, followed by a number of statements. Their task is to decide if the statements are "True", "False" or if they "Cannot tell" from the information provided. They are to assume that everything that is said in the passages is true.

The difference between spatial and verbal abilities also affect both females' and males' strategy use. Since many mathematical problems could be solved either by a spatial approach or by a verbal approach or by both of them, the discrepancy between spatial and verbal abilities would influence how students approach mathematical solutions (Krutetskii, 1976; Zhu, 2007). Battista, (1990) found that student with high spatial ability and low verbal ability might try to use more spatial strategies to solve mathematical problems, while those of high or low in both abilities might be more variable in strategy use.

Abstract Reasoning

The Abstract Reasoning assesses students' ability to identify patterns amongst abstract shapes. The items include irrelevant and distracting material which can lead the individual to unsatisfactory solutions. The non-critical person may remain satisfied with such solutions. The test, therefore, measures the ability to change track, critically evaluate and generate hypotheses which can be relevant in the development of new ideas and systems.

Abstract reasoning ability is important in mathematical performance because it enables students to apply what they learn in complex ways. Many students with learning disabilities have weaknesses in abstract reasoning and can benefit from direct instruction in math problem-solving skills. Students taking higher level of mathematics courses would benefit from training in abstract reasoning and problem solving, from computational practice, and from generally being more comfortable in working with numbers (Pallas and Alexander, 1983, Zhu,2007).

Numerical Reasoning

Numerical Reasoning Test consists of information is provided that requires students to interpret it and then apply the appropriate logic to answer the questions. In other words, students need to work out how to get the answer rather than what calculations to apply. Sometimes the questions are designed to approximate the type of reasoning required in the workplace.

Emeke and Adegoke (2001) examined the effect of test response mode, students' numerical ability and gender on the cognitive achievement of senior secondary school. The study revealed that the higher the numerical ability of students, the better their performance in the Physics achievement test. Adu (2002) tested the influence of quantitative ability and gender among other independent variables on students' academic achievement in Economics. The study found a significant influence of quantitative ability on students' academic achievement. Ursos and Bauyot (2006) showed that a moderate correlation exists between Numerical Ability Test and Achievement Test in College Algebra. Using least squares method, a mathematical model was defined by the equation $\hat{y}=38.788+0.234x$.

Mathematical Problem Solving, cognitive abilities and different hormones

Testosterone

Testosterone is a steroid hormone from the androgen group. On average, an adult human male body produces about ten times more testosterone than an adult human female body, but females are more sensitive to the hormone (Dabbs et al,2000). Testosterone has been associated with higher performance on spatial tests, and lower performance on verbal tests (e.g.,Christiansen and Knussman, 1987; Gouchie and Kimura, 1991; Hampson, 1990; for reviews, see Christiansen, 1998;Kimura, 2000). The predominant assumption is that testosterone influences cognition neuroanatomically, by shaping the development of brain structures and/or by activating these structures after puberty (e.g., Aleman et al., 2004; Gouchie and Kimura, 1991; Postma et al., 2000; Resnick et al., 1986). However, according to Wingfield's challenge hypothesis, testosterone should only influence social behavior when status is threatened or challenged (Wingfield et al., 1987). The substantial body of research supporting this hypothesis suggests that the link between testosterone and cognitive performance might be moderated by an individual's status in a particular situation. Also Geschwind's theory of prenatal hormonal effects (in Halpern, 2000; Halpern, Wai and Saw, 2005) assumes that higher levels of prenatal testosterone in males would result in a greater level of right-brain dominance, with which males would develop cognitive ability patterns that are more closely associated with right hemisphere functioning. Therefore, because both mathematical reasoning and spatial abilities are under greater control by the right hemisphere, males outperform females on mathematical reasoning , spatial tasks and abstract reasoning.

On a math test and on an analytical test, individuals with high levels of testosterone perform better in a high status position than in a low-status position. Also consistent with predictions, these changes in cognitive ability are accompanied by changes in physiological arousal , (high testosterone individuals are less aroused in a high- status position), and also in attention (high testosterone individuals focus more on their status in a low-status position) (Newman et al,2005) .

Another finding about testosterone and achievement is that females have long faced negative stereotypes about their math abilities, and a reminder of these stereotypes possess a potential threat to status. When primed with a negative stereotype, only high testosterone females showed a decrease in math performance. Males, on the other hand, face positive stereotypes about their math abilities, and a reminder of these stereotypes presents an opportunity to enhance status. Thus, high testosterone males outperform low testosterone males, but only when primed with a positive stereotype (Josephs, et al,2003).

Prenatal testosterone may have an impact on certain numerical skills that are thought to be right-hemisphere dominant. The right intraparietal sulcus (IPS) is activated when making numerical comparisons (e.g., magnitude judgments) and for non-symbolic numerosity coding (a subset of the number sense skills described above), whilst the left IPS develops as a function of experience with numerical symbols and is activated for the retrieval of precise numerical information, such as arithmetical facts (e.g., Chochon, Cohen, Van De Moortele, & Dehaene., 1999; Piazza, Mechelli, Price,

& Butterworth, 2006; Rivera, Reiss, Eckert, &Menon, 2005). Testosterone seems to influence the right hemisphere that is where our math, science, reasoning, and abstract thinking take place.
To date no reports have been published on how testosterone levels in human body respond to math performance and cognitive abilities for the university students. This study for the first time intends to discuss the relationship between hormones, cognitive abilities and mathematical performance among university students.

Thyroid-Stimulating Hormone (TSH)

Thyroid-stimulating hormone (TSH) also known as thyrotropin, is a peptide hormone synthesized and secreted by thyrotrope cells in the anterior pituitary gland, which regulates the endocrine function of the thyroid gland. TSH stimulates the thyroid gland to secrete the hormones thyroxine (T4) and triiodothyronine (T3).

Prolactin

Prolactin (PRL), also known as luteotropic hormone (LTH), is a protein that in humans is encoded by the PRL gene and secreted by the pituitary gland. Prolactin stimulates lactation (milk production). It also has many other functions, including essential roles in the maintenance of the immune system.
Significant correlation has been found between day-to-day changes in anxiety and stress hormones, cortisol and prolactin. Significant correlation has also been observed between plasma prolactin, testosterone and rank position for dominance/aggression. It is concluded that under some circumstances social interaction may modify endocrine status in humans (Jeffcoate et al,1986).

Thyroxine (T4)

Thyroxine, or 3,5,3',5'-tetraiodothyronine (often abbreviated as T4), a form of thyroid hormones, is the major hormone secreted by the follicular cells of the thyroid gland. Thyroxine is synthesized via the iodination and covalent bonding of the phenyl portions of tyrosine residues found in the initial peptide, thyroglobulin, which is secreted into thyroid granules. These iodinated diphenyl compounds are cleaved from their peptide backbone upon being stimulated by thyroid-stimulating hormone.
Again no evidence has yet been reported on the relationship between cognitive abilities, mathematical performance and testosterone, Thyroxine, TSH and prolactin levels in blood for university students group.

Research Framework

Our research question is: Is there any relationship between students' levels of testosterone, Thyroxine, TSH and prolactin and their mathematical performance and cognitive abilities? The review of literature reveals that testosterone may have some impact on students' mathematical performance and cognitive abilities but these results do not concern to university students. For other hormones no evidence has yet been reported so an exploratory position is taken in this study.
Our hypotheses are as follows:
Hypothesis 1. An exploratory position is taken to examine the association between testosterone level, mathematical performance and cognitive abilities for this university students' sample.
Hypothesis 2. An exploratory position is taken to examine the relationship between TSH level, mathematical performance and cognitive abilities for this sample.
Hypothesis 3. An exploratory position is taken to examine the association between Prolaction level, mathematical performance and cognitive abilities for this sample.

Hypothesis 4. An exploratory position is taken to examine the relationship between T4 level, mathematical performance and cognitive abilities for this university students' sample.

2. Method

Participants

109 students including 34 girls (18-19 years old) and 75 boys (18-19 years old) were selected among the students in the school of Mathematical Sciences at Ferdowsi University of Mashhad using random multistage stratified sampling design.

Instruments

The participants were required to take the following tests:

1- Verbal Critical Reasoning Test 2- Numerical Reasoning Test
3-Spatial Ability Test 4-Abstract Reasoning Test
5-Math Exam

Procedure

After collecting data from students', all the point was calculated from 100. Also 5cc blood was taken from participants by nurses for measuring the level of testosterone, prolactin , TSH and T4 . Students whom the level of hormones in their blood was above the sample mean were labeled as high hormones group and those who have low than the sample mean labeled as low hormones group. Authors should note that each sample mean for female and male calculated individually because the level of some hormones like testosterone in the blood of male and female are different.

Verbal Critical Reasoning Test

Critical reasoning questions require students to demonstrate their ability by making logical decisions and even recognizing that insufficient data have been provided for a definitive answer to be reached, as would be the case in many real-life situations. This verbal critical reasoning test consisted of 8 questions that students should answer as many as they can in 20 minutes. The test has been created by Newton and Bristoll and is available online from: http://www.psychometric – success.com. Here is a typical question of this exam:

Pedro goes either hunting or fishing every day. If it is snowing & windy then Pedro goes hunting. If it is sunny and not windy then Pedro goes fishing. Sometimes it can be snowing and sunny. Which of the following statements must be true?

A: If it is not sunny and it is snowing then Pedro goes hunting.
B: If it is windy and Pedro does not go hunting then it is not snowing.
C: If it is windy and not sunny then Pedro goes hunting.
D: If it is windy and sunny then Pedro goes hunting.
E: If it is snowing and sunny then Pedro goes hunting

Numerical Reasoning Test

Numerical Reasoning Test consisted of 22 questions that students should answer as many as they could in 20 minutes. It has been created by Newton and Bristoll and is available online from: http://www.psychometric –success.com. Here are two typical question of this exam:

1) Identify the missing number at the end of the series.
662, 645, 624, 599,…

A	*B*	*C*	*D*	*E*
587	*566*	*589*	*575*	*570*

2) Identify the missing number

4	14
35	26

11	31
73	?

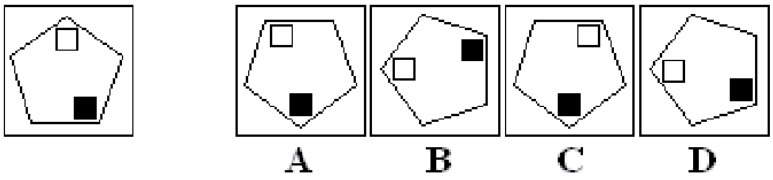
A	B	C	D	E
51	56	45	55	52

A B C D E

Spatial Ability Test

Spatial Ability Test consisted of 45 questions that students should answer as many as they could in 20 minutes. It has been created by Newton and Bristoll and is available online from: http://www.psychometric –success.com. Here is a typical question of this exam:

Which figure is identical to the first?

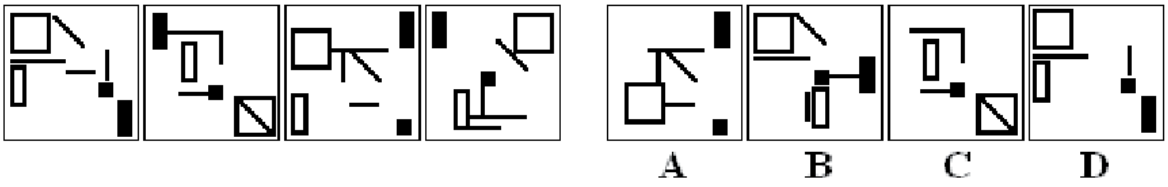


A B C D

Abstract Reasoning Test

Abstract reasoning tests use diagrams, symbols or shapes instead of words or numbers. They involve identifying the underlying logic of a pattern and then determining the solution. Because they are visual questions and are independent of language and mathematical ability, they are considered to be an accurate indicator of students' general intellectual ability. Abstract Reasoning Test consisted of 25 questions that students should answer as many questions as they could in 20 minutes. It has been created by Newton and Bristoll and is available online from: http://www.psychometric –success.com. Here is a typical question of this exam:

Which figure completes the series?



A B C D

Math Exam

In the present study the students' scores on the mathematics exam taken at the end of the first term in the academic year 2010-2011 were obtained from Ferdowsi University student office and used

as the basis for judging about students' math performance. This test is of utmost importance to the students.

3. Results

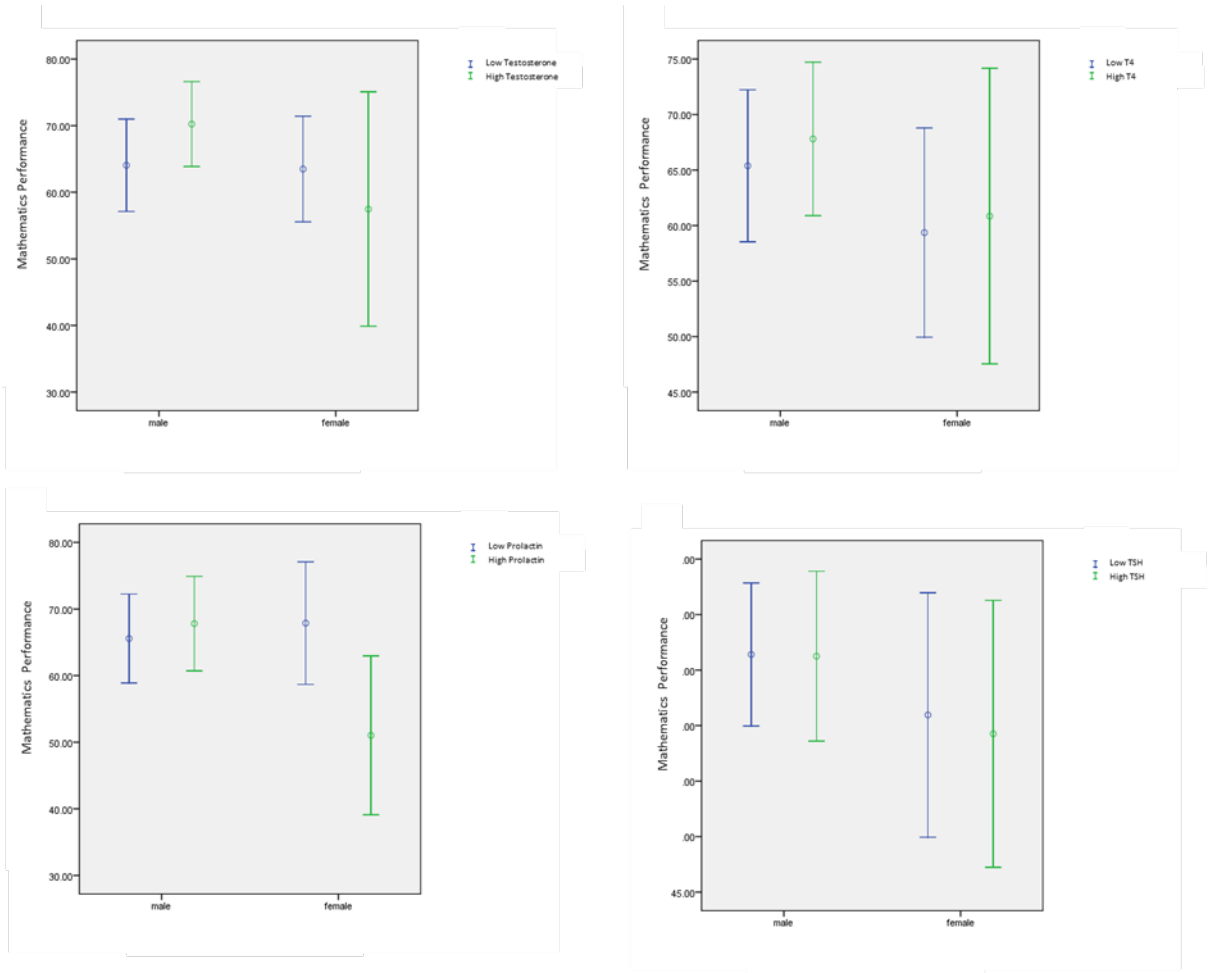
Math Performance and level of hormones

The Mann Whitney U test is a non-parametric test that is useful for determining if the mean of two groups are different from each other or not. The result of Mann Whitney U test for two groups of Low and high testosterone male students' showed that they had no significant difference in terms of mean scores obtained in Math exam. Nevertheless according to Figure 1 male students' with high testosterone showed better performance than the low ones in this sample. Also, for female students, no significant difference was found according to T-test for the two groups of low and high testosterone hormones but the result was reversed; female students with low testosterone exhibited better performance in mathematical task than the high ones. The same result for thyroxine hormone was obtained in male students, while for female students no significant difference was found in terms of mathematical performance between the two groups of low and high thyroxine hormone.

Also no significant difference was found between mathematical performance of two groups of low and high TSH for both male and female students as presented in Table 1.

Finally, in term of prolactin no significant difference was observed between mathematical performance of male students. Nevertheless, students' mathematical performance was found to be better in high prolactin group. For female students opposite result was obtained so that those who were low in prolactin showed significantly better mathematical performance than other group.

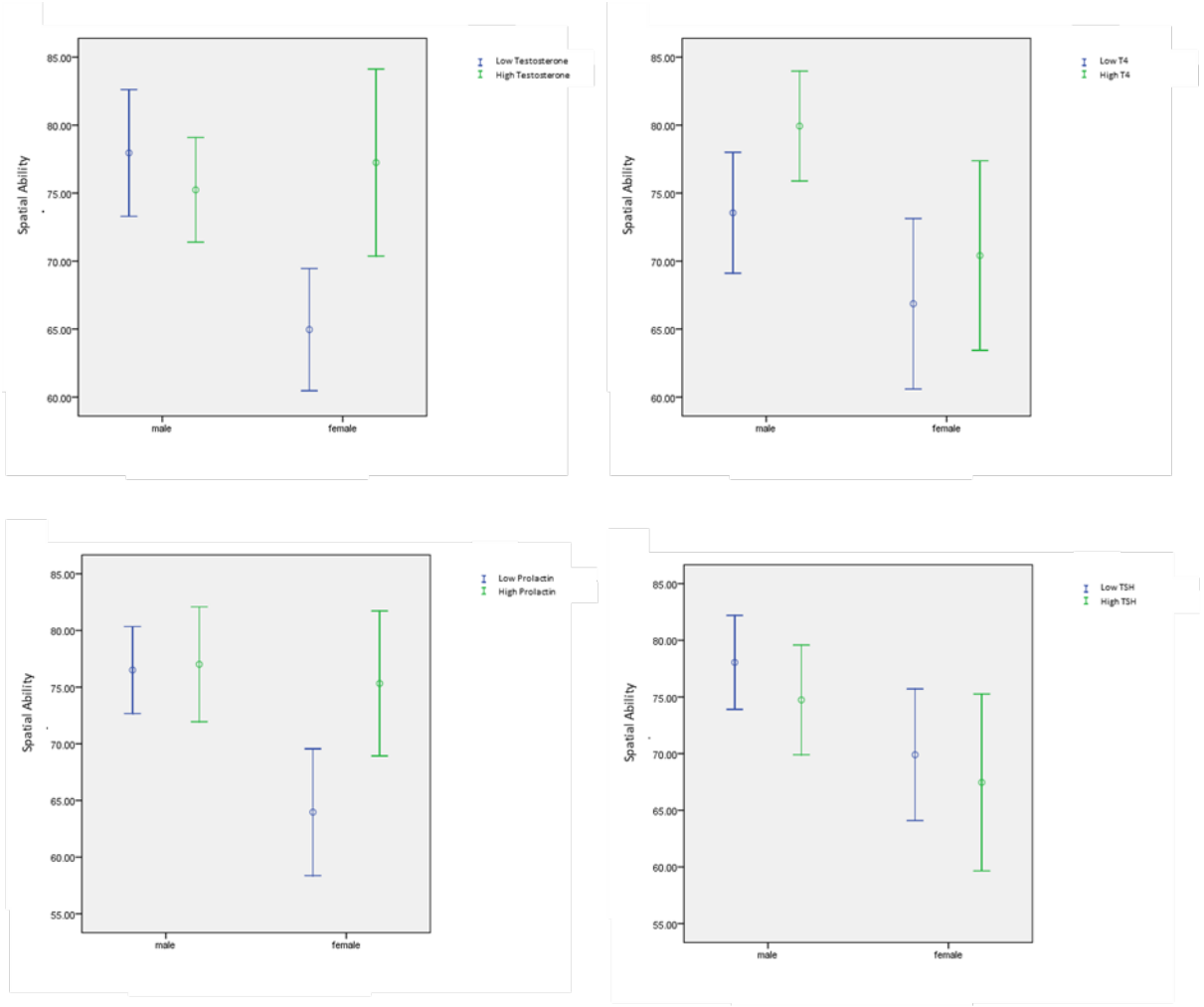
Figure1. Math Performance and level of Hormones



Spatial Ability and level of hormones

For Spatial Ability test, three significant results obtained; first, female students with high testosterone level significantly better performed than those with low level of this hormone. Second, male group of high in T4 hormone had a better performance than those low in this hormone. And third female students with high prolactin achieved higher performance than the others. It should be noted that in this sample, for testosterone and TSH hormones in male students better performance was obtained by low hormone group, while for females better performance was achieved by group of high T4 and low TSH.

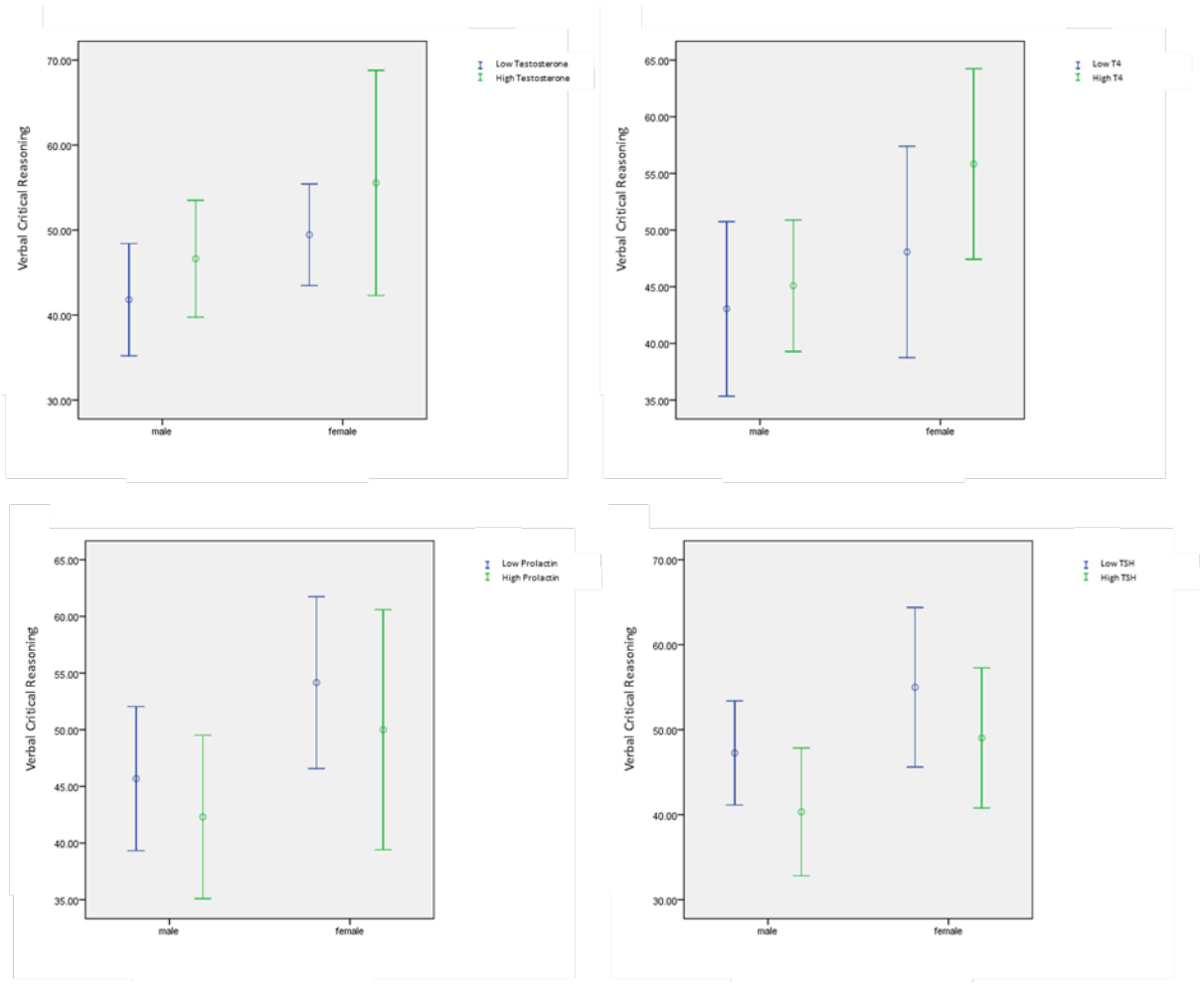
Figure2. Spatial Ability and level of hormones



Verbal Critical Reasoning and levels of hormones

The result of Mann Whitney U Test and T-test for two groups of low/high testosterone,T4,TSH and prolactin hormones in male and female students' showed no significant difference in terms of Verbal Critical Reasoning exam although in this sample for both male and female groups, better performance achieved in group of high level of Testosterone and T4 and low level of prolactin and TSH.

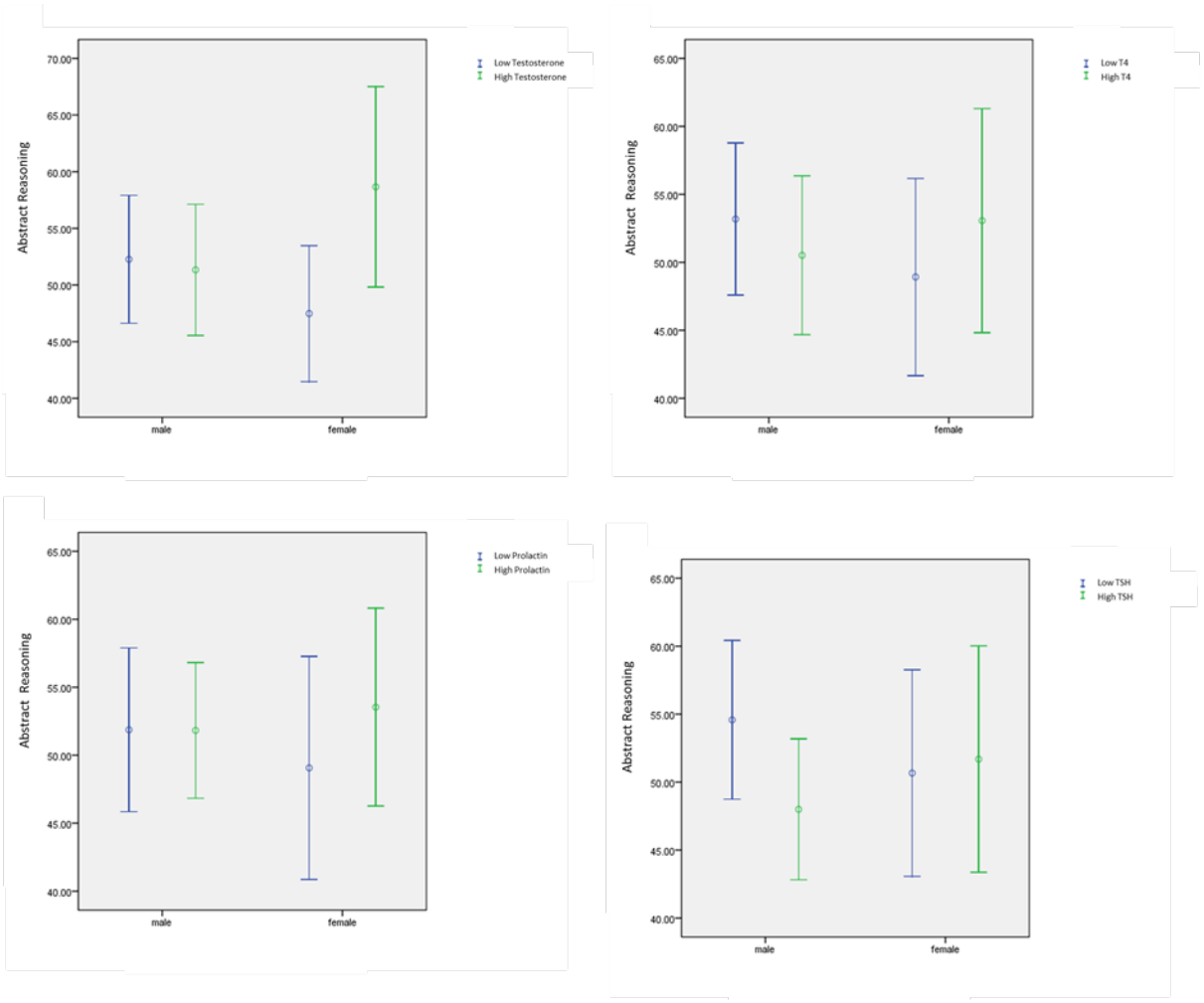
Figure3. Verbal Critical Reasoning and levels of hormones



Abstract Reasoning and level of Hormones

The result of T-test for two groups of high/low testosterone in female students showed significant difference in terms of Abstract Reasoning test with the group of high testosterone achieving better scores. In contrast for male students no difference was found between the two corresponding groups. For other hormones (T4,T.S.H and prolactin) the difference between male and female students of high/low groups was not significant. However, in this sample, male students with low T4 performed better than those with high level of the hormone, while for female ones the result was reversed. Regarding TSH better performance was achieved in male group of low hormone but for female students no difference was observed. In terms of prolactin male students showed no difference while females in group of high hormone obtained better performance in terms of Abstract Reasoning Test than the opposite group.

Figure4.Abstract Reasoning and level of hormones



Numerical Reasoning and level of hormones

The result of T-test for two groups of high/low testosterone in female students showed significant difference in terms of Numerical Reasoning with the high hormones group achieving better performance. For male students the same results was also observed. However difference was not significant. Regarding T4 hormone, both male and female students' achieved better performance at high level of hormone, although the difference was not significant.

For prolactin and TSH hormones no significant difference was found in terms of Numerical Reasoning Test. Nevertheless for male students low in TSH and females containing high level of the hormone better performance was observed. Finally for prolactin hormone, male students showed no difference but female ones achieving better performance at high level of the hormone.

Figure5. Numerical Reasoning and level of hormones

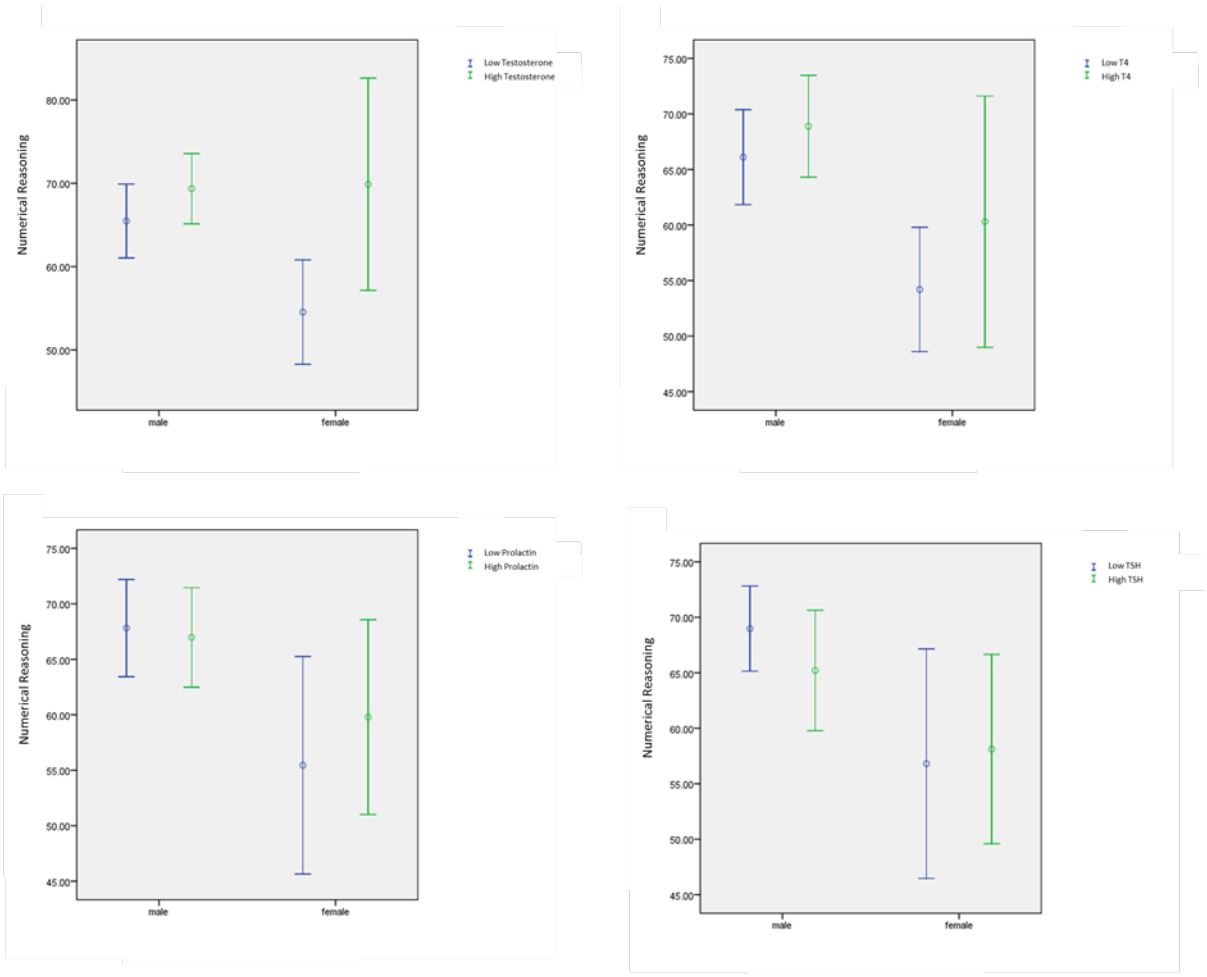


Table 1. Cognitive abilities, mathematical performance and the level of Testosterone, Thyroid-Stimulating Hormone, Prolactin and Thyroxine

Item	Two groups of high/low Testosterone for male students	Two groups of high/low Testosterone for female students	Two groups of high/low T4 for male students	Two groups of high/low T4 for female students	Two groups of high/low T.S.H for male students	Two groups of high/low T.S.H for female students	Two groups of high/low Prolactin for male students	Two groups of high/low Prolactin for female students
Math performance	.34	.47*	.39	.86*	.98*	.84*	.60	.03
Spatial Ability	.15	.01*	.03	.46*	.21	.61	.70	.01*
Verbal reasoning	.28	.48	.60	.11	.16*	.44	.48	.36
Abstract reasoning	.82*	.05*	.51*	.46*	.11*	.86*	.99*	.43*
Numerical reasoning	.27	.03*	.30	.36	.33	.85*	.71	.52*

*Result from T-test
Unflagged: Result from Mann-Whitney

4. Discussion

Male and female students differ not only in their physical attributes and reproductive function but also in many other characteristics, including the way they solve intellectual and math problems (Kimura,2002). Most important factor in the differentiation of males and females and indeed in differentiating individuals within a sex is the level of exposure to various sex hormones early in life (Kimura,2002). The results of this study offer a new way to conceptualize the relationship between various hormones and cognition literature. According to the forty tests (twenty for males and twenty for females) performed in this survey six significant differences were found between low and high hormone groups and mathematical performance as well as Cognitive abilities which are summarized here:

For females:

Students with low prolcation hormone, significantly better performed in mathematical performance.

Female students with high testosterone significantly better performed in terms of spatial ability test.

Female students with high prolactin performed better in spatial ability test in comparison to low in this hormone.

The two groups of high/low testosterone amongst female students showed significant difference in terms of abstract reasoning test with the group containing high level of hormone achieving better performance.

The difference between two groups of high/low testosterone in female students was found to be significant in terms of numerical reasoning test which the high testosterone group obtained superior results.

For males:

Group of high T4 performed better in spatial ability test.

As can be inferred from the results of this study, hormones in question have more effects on predictive factors of mathematical performance for female students than male ones. Five significant differences found for female students, in contrast just one significant differences were found for male students. Our results are in consistence with Dabbs et al (2000) findings that females are more sensitive to hormones.

Considering a few works carried out by others on the relation between the level of testosterone and cognitive abilities, it would be worth comparing the findings of the present study with the reported results. Literature survey shows that male students with high testosterone have better performance in cognitive ability and math performance while our findings reveals no significant difference between two groups of low and high testosterone hormone and mathematical performance for two groups of male and female. However in this sample the Superiority was found to belong to male students of high Testosterone which is in agreement with the results reported by Newman et al (2005). As shown before for male university students no significant difference was found between two groups of high and low testosterone and their cognitive abilities (spatial ability, verbal ability, numerical ability). This means that, the influence of this hormone on variables under investigation may decrease above the age of 18 for male students, although it has an important role in students' cognitive ability at younger ages as reported by others.(Christiansen and Knussman,

1987; Gouchie and Kimura, 1991; Hampson, 1990; for reviews, see Christiansen, 1998;Kimura, 2000).

Based on Kimura (2002) the relationship between testosterone and spatial ability of male and female is in reverse order. In other words, Female students with low testosterone level exhibited high spatial ability. In contrast, male students, better performance and higher special ability were linked with high level of testosterone. The results of this study are in line with these findings. Moreover, for math performance, abstract reasoning and also an inverse relation with the level of testosterone was observed.

One of the interesting results of this study is that female students with low prolcatin hormone, show significantly better mathematical performance. This may be due to the relationship existing between Prolactin and anxiety (Jeffcoate et al,1986) that high level of anxiety has negative influence on mathematical problem solving. (Ma and Xu, 2004; Rodarte-Luna and Sherry, 2008, Alamolhodaei, 2009). Also Dabbs et al (2000) reported that females are more sensitive to the hormones so these facts caused to this difference happened.

Researchers should note that Because of lack of evidence about the relationship between these factors and different hormones, the comparison of the results of this study to other researches summarized to paragraphs mentioned above.

It has been proved that any behavioral differences between individuals or groups must somehow be mediated by the brain (Kimura, 2002). Sex differences have been reported to due to structure and organization. Studies done on the role of sex hormones in human math behavior have highlighted this relationship. But yet there remain questions unanswered regarding how hormones act on human brain systems to produce the sex differences we described here (such as in play behavior or in cognitive patterns). Faverjon et al (2002) suggested that physical studies of the brain in predicting intelligence are largely arbitrary due to the inherent neuroplasticity of the organ and the multitude of ways that brain function can be influenced by the stimulating quality of the environment and hormonal influences. The authors believe that findings of this study can reveal some new results about the effects of different hormones on mathematical performance and cognitive abilities. Researchers of this study suggest other researchers around the world to continue this study on other levels and with more samples.

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