The relationship between predictive factors of mathematical performance and the level of Testosterone, Thyroid-Stimulating Hormone, Prolactin and Thyroxine

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Abstract: The relationship between some specific hormones (Testosterone - Thyroid-Stimulating Hormone-Prolactin-Thyroxine) and some predictive factors of mathematical performance in university students has been investigated in this study. According to the forty tests (twenty for males and twenty for females) performed in this research, six significant differences were found between low and high hormone groups and predictive factors of mathematical performance. 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 difference were found for male students. Also it should be mentioned that hormones in question have more effects on cognitive style of students than other variables in this study [Abbas Amani, Hassan Alamolhodaei, Farzad Radmehr. **The relationship between predictive factors of mathematical performance and the level of Testosterone, Thyroid-Stimulating Hormone, Prolactin and Thyroxine.** Journal of American Science 2012;8(4):201-212]. (ISSN: 1545-1003). http://www.americanscience.org.28

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1. Introduction

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). In this study researchers explore the relation between some specific hormones (i.e. Testosterone - Thyroid-Stimulating Hormone-Prolactin-Thyroxine) and some predictive factors of mathematical performance (Working Memory Capacity- Cognitive Style –Math anxiety-Mathematics attention-Mathematics Attitude) in university students.

Mathematical Problem Solving and predictive factors

In this section, why these variables are considered to be predictive factors of mathematical performance will be discussed:

Working Memory Capacity

Working memory refers to a mental workspace, that involved in controlling, regulating, and actively maintaining relevant information to accomplish complex cognitive tasks (e.g. mathematical processing) (Raghubar et al ,2010).As Baddeley (1986, 1990) defines , it is a system for temporary holding and manipulating of information during the performance of a range of cognitive tasks such as comprehension learning and reasoning. In fact, Baddeley’s (1990) model of working memory has been particularly useful in explaining a variety of thinking phenomena (Niaz and Logie 1993).

Working memory capacity (WMC) is essential for important cognitive abilities including reasoning, comprehension and problem solving (Engle,2002). Although WMC is related to short-term memory capacity, it also reflects general “executive attention” ensuring that memory is maintained in spite of interference or distractions. This ability enables controlled attention capability in situations involving distraction during memory and cognitive control tasks (Engle, 2002 ; Mayers,2011).

There are some considerable evidences suggesting that WM may be important for mathematics learning and problem solving. For instance, Adams and Hitch (1998) suggested that mental arithmetic performance relies on the recourses of working memory. Significant associations have been found between the phonological loop and mental arithmetic performance (Adams and Hitch, 1998; Javris and Gathercole, 2003; Holmes and Adams, 2006). Moreover, (Alamolhodaei ,2009; Farsad & Alamolhodaei,2009 and Pezeshki et al,2011) have found that the students with high WMC, are more capable of solving math word problems compared to those with low WMC .

Cognitive Style (Field Dependency)

Cognitive style differences influence the acquisition and demonstration of cognitive skills necessary for self-formation such as differentiation, organization and integration. Field independence-dependence) FI-FD(is the ability to separate an element from an embedding context. Individuals adept at locating a simple figure within a larger complex figure are referred to as field independent, while those at the opposite end of the continuum are referred to as field dependent (Witkin and Goodenough, 1977).

Several researchers have demonstrated the importance of field dependency in science education and mathematical problem solving, in particular word problems (Witkin and Goodenough 1981; Talbi 1990; Johnstone and Al-Naeme 1991, 1995; Alamo; Sirvastava 1997; Ekbia and Alamolhodaei 2000; Alamolhodaei 2002, 2009). It was found that FI students tend to get higher results than FD students in calculus problem solving at university level. Moreover, school students with FI cognitive style achieved much better results than FD ones in mathematical problem solving, particularly word problems.

Mathematics Anxiety

Mathematics anxiety is one of the common attitudinal and emotional factors that have attracted attention in recent years. Over the past thirty years, studies have shown mathematics anxiety to be a highly prevalent problem for students (Baloglu and Koçak, 2006; Betz, 1978; Jain and Dowson, 2009; Ma and Xu, 2004; Rodarte-Luna and Sherry, 2008, Alamolhodaei, 2009). It has been directly or indirectly, affecting all aspects of mathematics education as one of the most commonly investigated constructs in mathematics education (Çatlıoğlu et al., 2009). In fact, math anxiety may be defined as a feeling of tension, apprehension, or fear that interferes with math performance (Richardson & Suinn, 1972). A number of studies have been carried out over the last few decades on math anxiety investigating its effects upon mathematical activities across all grade levels, k-college. They all revealed that math anxiety is often associated with low performance in mathematical activity and in particular solving math problems (Hembree, 1990; Bessant, 1995; Ma, 1999, Mark and Woodard, 2004; Ma & Xu, 2004; Baloglu & Kocak, 2006; Alamolhodaei, 2009, Pezeshki et al, 2011).

Math Attitude

Many researchers report that positive mathematical beliefs, attitudes, and feelings will lead to increased mathematical achievement (Grootenboer, 2003a, Wilkins , & Ma,2003, Hassi & Laursen,2009). Attitudes towards mathematics appears to be very important in relation to differences in achievement as well as in participation in mathematics courses. According to literature, attitude can predict achievement and that achievement, in turn, can predict attitude (Meelissen & Luyten,2008, , Fardin et al, 2011). Negative attitudes and emotions, together with inadequate self regulatory behaviors, are often connected with students' preventive beliefs and perceptions in mathematics learning situations (DeBellis & Goldin, 2006; Malmivuori, 2001; McLeod, 1992). Such beliefs and behaviors derive from students' previous classroom experiences, both positive and negative; they are highly stable and difficult to change (e.g., Bishop, 2001; Cobb, Yackel & McCain, 2000).

Mathematics Attention

Mathematics is a way of thinking and requires a great deal of attention, particularly when multiple steps are involved in problem solving process. However, attention is a controversial concept but its large scale treatments could be found in recent studies (Cowan et al,2005). There has been demonstrated a close relation between attention and memory in the limit capacity system (Styles,2005). At least two dimensions of attention may be considered, the attention control and its scope. These two dimensions of attention are not necessarily in conflict. Individuals who excel at controlling could be those who have the largest scope of attention (Cowan et al, 2005 & Styles, 2005).

At the heart of math attention is the issue of how many tasks can be done at the same time to reach a solution. Alamolhodaei & Abbasi, (2010) found that mathematical attention is a cognitive function which allocates the math information and Z-demands (amount of information processing required by math task) of tasks to a different level of consciousness. The process of attention could help students with meaningfull level learning of mathematical activities. In contrary, inattention is the most and widespread problem of learners. Inattention is a risk factor for poor mathematics achievement (Tannock, 2008).

According to Alamolhodaei, Farsad and Radmehr(2012) math attention has the highest path coefficient to mathematical performance between math attitude, math attention ,field dependency and metacognitive ability. During math instruction, students who have attention difficulties often miss some important parts of the content.

Mathematical Problem Solving, predictive factors 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;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.

Testosterone supplementation has been shown to improve working memory in older men, while similar enhancement of working memory has not been found in older women supplemented with estrogen. In men, testosterone and estrogen effects are reciprocal—with better working memory related to a higher testosterone to estrogen ratio (Janowsky et al ,2000). To date no reports have been published on how testosterone levels in human body respond to math attitude, anxiety and attention. Also literature survey shows that university students have never been included in these studies. This study for the first time intends to discuss the relationship between hormones and predictive factors of 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 these predictive factors of mathematical performance and testosterone, TSH and prolactin levels in blood for university students group.

In this study researchers explore the relation between some specific hormones (i.e. Testosterone - Thyroid-Stimulating Hormone-Prolactin-Thyroxine) and some predictive factors of mathematical performance (Working Memory Capacity- Cognitive Style –Math anxiety-Mathematics attention-Mathematics Attitude) in university students.

2. Material and Methods

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.

Procedures

The participants were required to take the following tests:

1-Digit Span Backwards Test (DBT)
2- Mathematics Anxiety Rating Scale (MARS)
3- Cognitive style (FD/FI) test
4-Modified Fennema-Sherman Attitude Scales
5-Mathematics Attention Test (MAT)

After collecting data from students', all the point was calculated from 100. Also 5cc blood was taken from participants for measuring the level of testosterone, prolactin , TSH and T4 . Students who 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.

Digit Span Backwards Test (DBT)

For measuring students' working memory capacity (WMC), DBT has been showed to be the most suitable test (Case 1974;Talbi 1990; Alamolhodaei, 2009 and Pezeshki et al, 2011). To this end, the digits were read out by an expert and the students were asked to listen carefully, then turn the number over in their mind and write it down from left to right on their answer sheets. WMC was originally has seven plus or minus two storage unit as Pascual Leoni described.

Mathematics Anxiety Rating Scale (MARS)

The level of anxiety was determined by the score attained on the Math Anxiety Rating Scale (MARS), which has been recently developed in the Faculty of Mathematical Sciences, Ferdowsi University of Mashhad(Alamolhodaei,2009;Amani et al,2011). The MARS for this research was newly designed by the researcher according to the inventory test of Ferguson (1986). It consists of 32 items, and each item presented an anxiety arousing situation. The students decided the degree of anxiety and abstraction anxiety aroused using a five rating scale ranging from very much to not at all (5–l). Cronbach's alpha, the degree of internal consistency of mathematics attention test items for this study was estimated to be 0.94.

Cognitive style (FD/FI) Test

The independent variables were cognitive style and the position of a learner on each of the learning style dimensions (FD and FI) was determined using the Group Embedded Figures Test (GEFT) (Oltman et al. 1971). In this test, subjects are required to disembed a simple figure in each complex figure. There are 8 simple and 18 complex figures, which make up the GEFT. Each of the simple figures is embedded in several different complex ones. Students' cognitive styles were determined according to the criterion used by other researchers (Case 1974; Johnstone et al. 1993; Alamolhodaei ,2009).

Modified Fennema-Sherman Attitude Scales

In an effort to assess students' attitudes towards math, Elizabeth Fennema and Julia A.

Sherman constructed the attitude scale in the early 1970's. The scale consists of four subscales: confidence scale, usefulness scale, teacher perception scale and a scale that measures mathematics as a male domain .Each scale consists of 12 items of which six measures a positive attitude and the remaining measure a negative attitude. This scale could provide useful information about that student's attitude(s) towards math. Because this scale was originally designed many years ago and the subtle meanings and connotations of words have changed since, Doepken, Lawsky and Padwa were modified it. The authors used the modified version of the test which can be obtained from this URL: http://www.woodrow.org/teachers/math/gender/08scale.html

Mathematics Attention Test (MAT)

The level of math attention was determined by an unpublished attention test which has been developed in the school of Mathematical Sciences, Ferdowsi University of Mashhad. In this task students respond to 25 questions which arranged according to Likert scale from very little to too much. Cronbach's alpha, the degree of internal consistency of mathematics attention test items was estimated to be 0.86. Here are some typical questions of this exam:

How much attention do you have in each situation?

Question Number	Question
1	When the subjects are offered by teacher in the classroom.
2	When studying the math lessons that you have been learned.
3	When the math teacher is teaching and you need to write and listen simultaneously.
4	When studying and learning mathematics in a group.
5	When the math course materials are to be tangible and concrete.
6	When teacher directly monitors the process of your math problem solving.
7	When the math course materials are to be tangible and concrete.
8	When the math course materials are abstract and you have no idea about it in your mind.

3. Results

Cognitive style and level of hormones

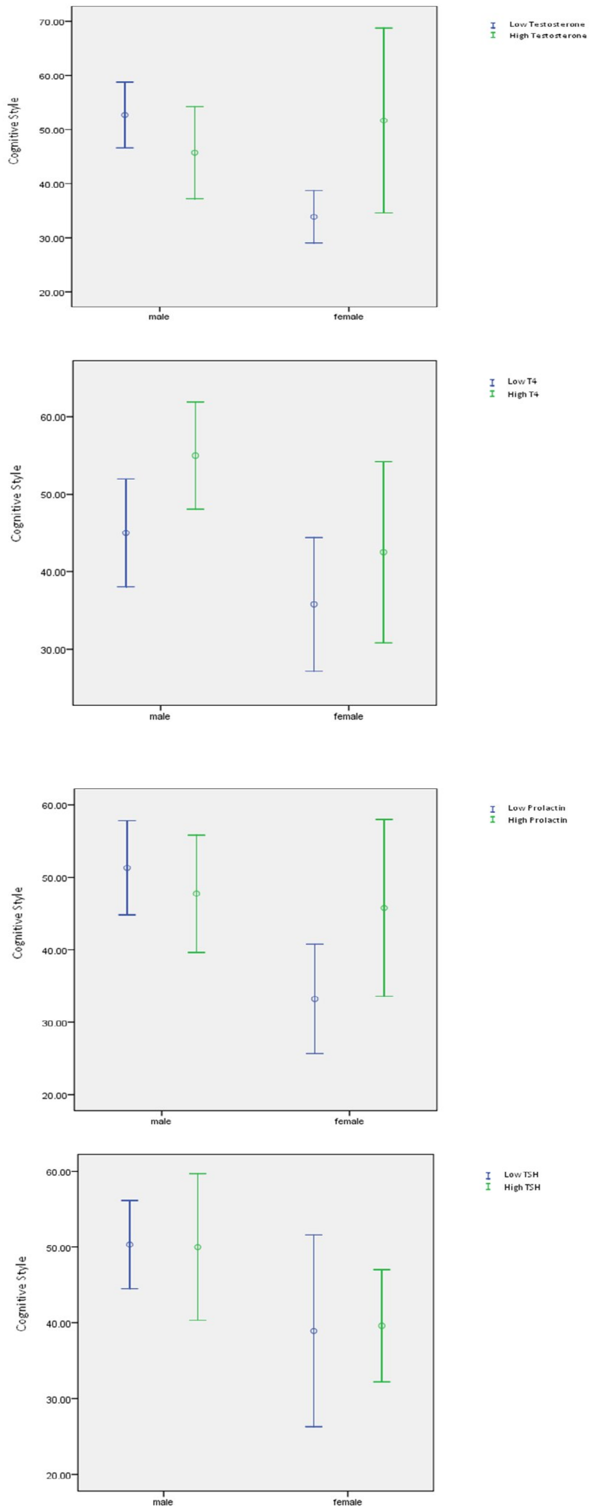
The result of T-test for two groups of low and high testosterone male students showed that they had no significant difference in terms of mean scores obtained in cognitive style test with p-value=.18 while as can be seen in Figure 1 male students of low in testosterone had better performance than the other group. On the other hand, the results of T-test for two groups of Low and high testosterone female students' showed that they had significant difference in terms of mean scores obtained in cognitive style test with p-value=.07 at the confidence level of 90 percent . It was found according to graph error bar that female students with high testosterone had better performance than those low in testosterone (Figure 1).

Male students with high level of T4 had significantly better performance than those with low level of this hormone according to the result of Mann Whitney U test with p-value=.05, but for female students no significant difference obtained between the two groups of high and low T4. Nevertheless, according to graph error bars in Figure1 female students with high T4 hormones had better performance than the other group in this sample.

The result of Mann Whitney U test for the two groups of low and high TSH hormone showed that there existed no difference between male students in term of cognitive style test according to Table 1. Also same results were obtained for female students.

The result of Mann Whitney U test for two groups of low and high prolactin hormone showed that there was no difference between male students in terms of cognitive style test according to Table 1, while male students with low prolactin hormone showed better performed in cognitive style test than those with high level of this hormone. On the other hand for female students according to the result of T-test, high prolactin group had significantly better performance than low prolactin group at a confidence level of 90 percent.

Figure1. Cognitive style and level of hormones

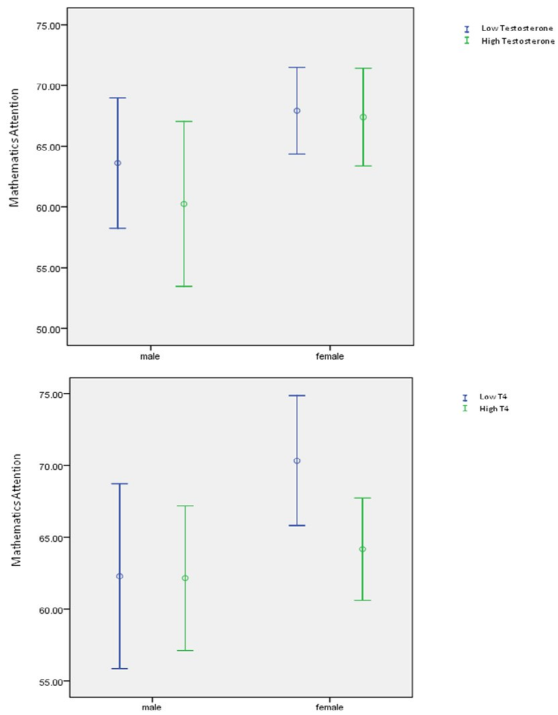


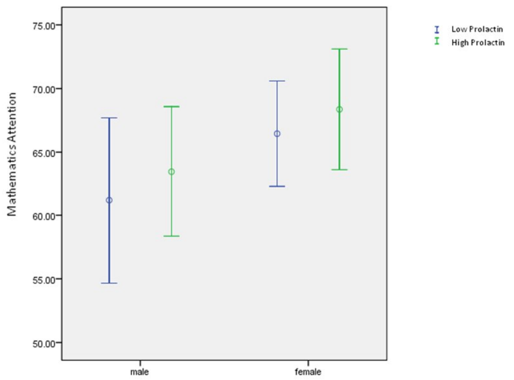
Math Attention and level of hormones

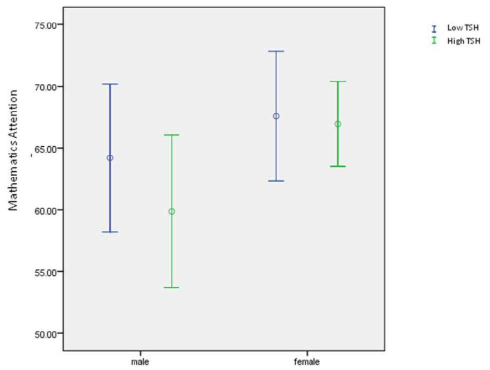
The result of Mann Whitney U test for two male groups of low and high testosterone hormone showed that there was no significant difference between their Math Attention Test. Nevertheless, male students with low testosterone exhibited more math attention in this sample than those with high level of this hormone. Same result was also found for female students. Regarding T4 hormone the result was different for the two groups of female students in contrary to testosterone hormone in that these with low T4 obtained significantly more math attention than the other group. For male students no difference was found between the attention of the two groups of low and high T4.

The result of Mann Whitney U test for two groups of low and high TSH hormone in male and female students showed no difference in term of their Math Attention Test scores. Finally, for the two groups of low and high prolactin no significant difference was observed in terms of their math attention test results while in this sample for students with high prolactin , math attention was found to be higher than those with low level of this hormone both for males and females.

Figure2. Math Attention and level of hormones



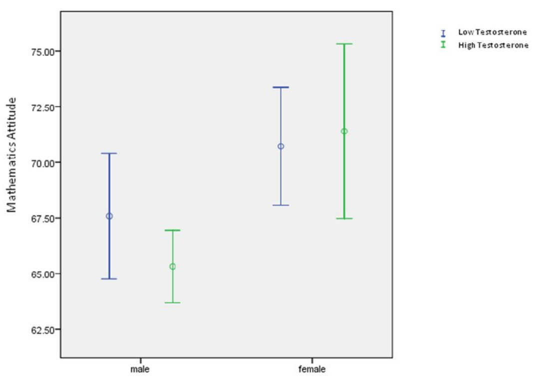


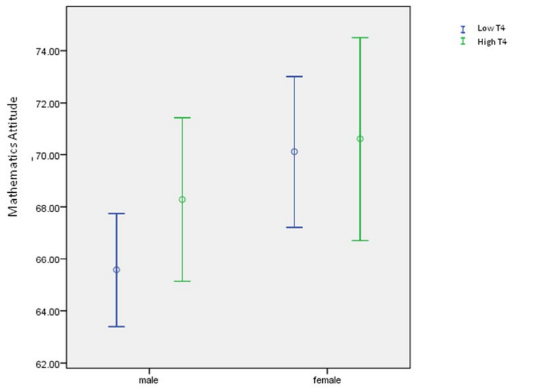


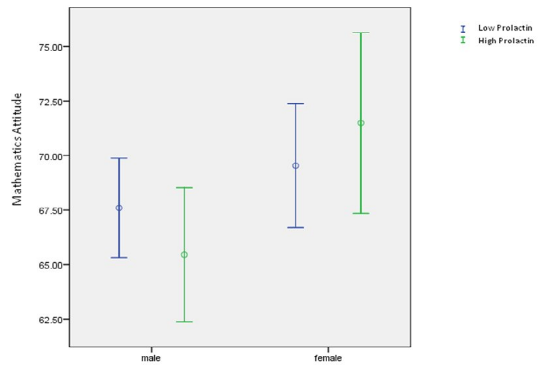
Math Attitude and level of hormones

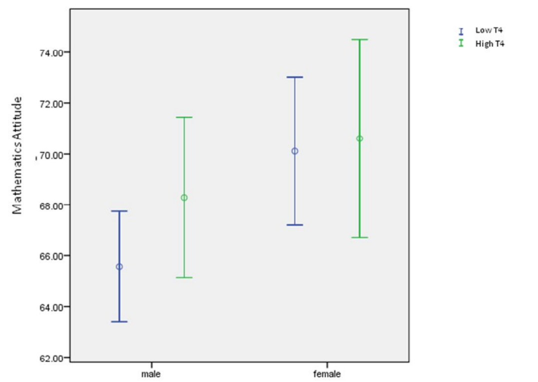
The result of T-test for two male groups of low and high hormones (e.g Testosterone, T4,TSH and prolactin) showed no significant difference in terms of their math attitude test although more positive attitude toward mathematics in this sample exhibited by low level of testosterone and prolactin, and high levels of T4 and TSH(Figure 3). For female group, significant difference was found between math attitude of low and high TSH group in regard of superiority for high hormone groups with confidence level of 90. For other hormones (e.g. Testosterone, T4 and Prolactin) no significant difference was obtained.

Figure3. Math Attitude and level of hormones





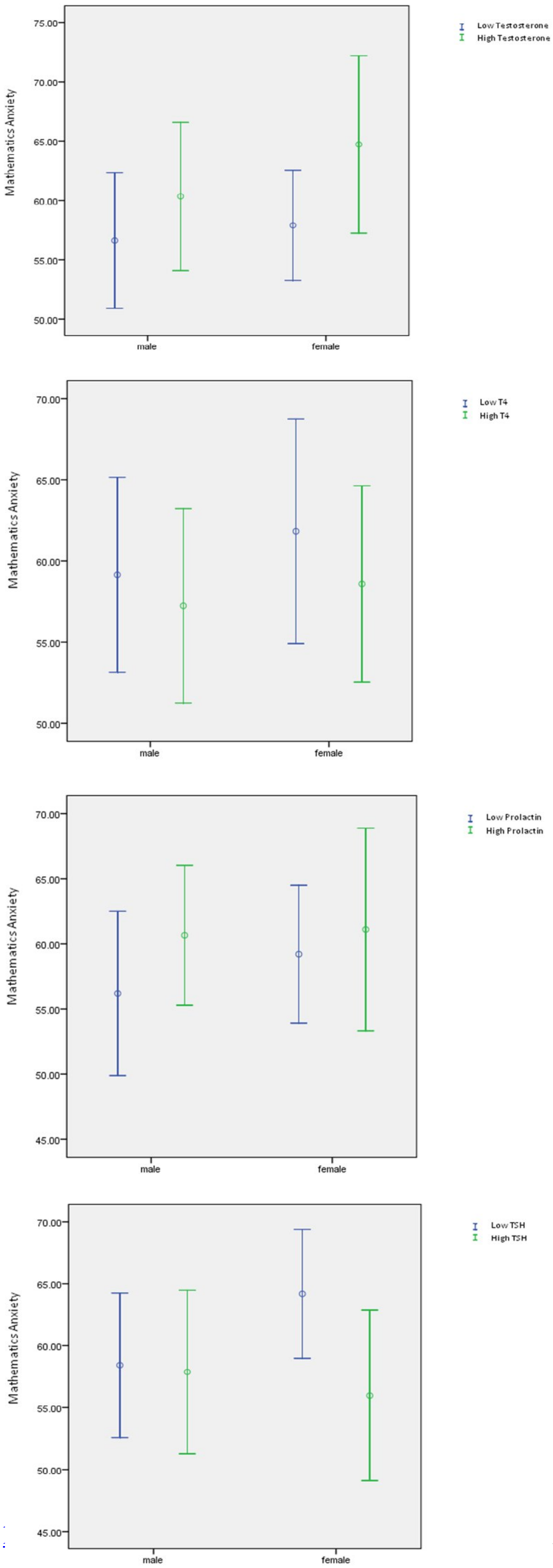




Math Anxiety and level of hormones

The result of T-test for two groups of high/ low testosterone and T4 hormones showed no significant difference in terms of the scores obtained on Math Anxiety Test by both female and male students, although both for male and female with high level of testosterone appeared to have more math anxiety than the opposite group (Figure 4). On the other hand, concerning T4 more math anxiety was shown by both female and male students low in this hormone. For Prolactin the results was the same as for testosterone. But for TSH in male students the results indicated no difference between math anxiety of two groups of high/low in this hormone. For female students, in contrary significant difference was found between two groups of high/low TSH hormones with higher math anxiety for this low level of TSH at a confidence level of 90 percent.

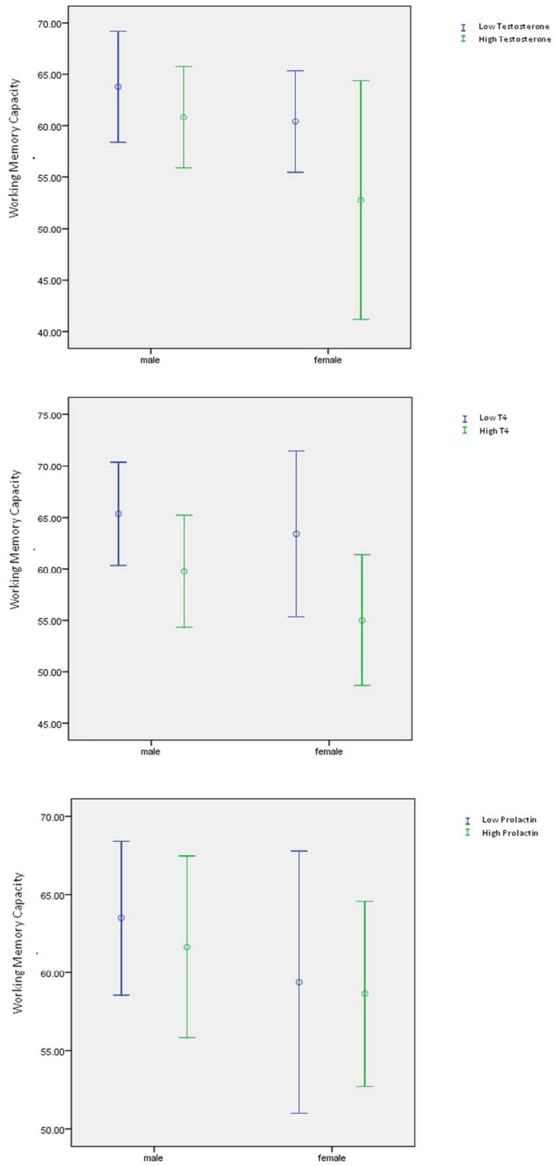
Figure4. Math Anxiety and level of hormones



Working Memory Capacity and level of hormones

The result of Mann Whitney U test for two male and female groups of low/high testosterone, T4, T.S.H and prolactin showed no significant difference in terms of Working Memory Capacity (Figure5) nevertheless, for testosterone and T4 hormones in both female and male students in this sample, the superiority of WMC was found to be obtained at lower level.

Figure5.Working Memory Capacity and level of hormones



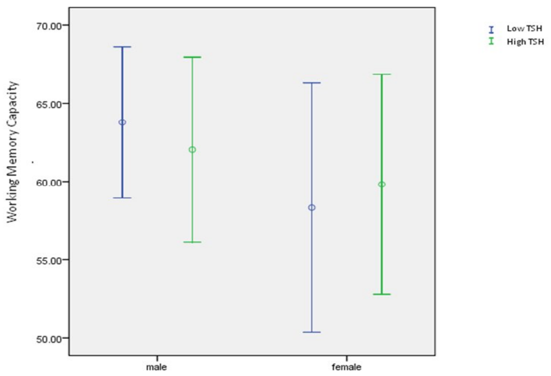


Table1. Predictive factors of mathematical performance and different hormones

Item	Cognitive Style	Math Attention	Math Attitude	Math Anxiety	Working memory capacity
Two groups of high/low Testosterone for male students	.18*	.49	.17*	.39*	.39
Two groups of high/low Testosterone for female students	.07*	.17	.87	.13*	.69
Two groups of high/low T4 for male students	.05	.64	.15*	.65*	.14
Two groups of high/low T4 for female students	.37*	.04*	.84*	.48*	.15
Two groups of high/low T.S.H for male students	.92	.17	.20*	.90*	.69
Two groups of high/low T.S.H for female students	.46	.85*	.06*	.07*	.83
Two groups of high/low Prolactin for male students	.49	.94	.26*	.30*	.46
Two groups of high/low Prolactin for female students	.09*	.55*	.43*	.68*	.83

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

4. Discussions

The results of this study offer a new way to conceptualize the relationship between various hormones and cognition literature. According to the forty test (twenty for males and twenty for females)performed in this survey six significant differences were found between low and high hormone groups and predictors' of mathematical performance which are summarized here:

For females:

•Students with high testosterone hormone had better performance in cognitive style test.

•High Prolactin group showed significantly better performance in terms of cognitive style test.

•Students low in T4 hormone proved to have significantly more math attention.

•Regarding the attitude towards mathematics, significant difference obtained between low/high TSH with the high hormone group showing more positive attitude toward mathematics.

•For math anxiety, significant difference was obtained between two groups of high/low TSH hormones with the low hormone group having more math anxiety.

For males:

•Students with level of high T4 exhibited significantly better performance in cognitive style 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 two 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.

Cognitive style as a predicative factor of mathematical performance (Witkin and Goodenough 1981; Talbi 1990; Johnstone and Al-Naeme 1991, 1995;Alamolhodaei,2009) has relationship with Testosterone and Prolactin for females and for males with T4.This study revealed that this factor is more sensitive to hormones in question than other variables in this study.

Males and females with high level of Prolactin appeared to have more math anxiety than the opposite group in this sample. It's may be due to the positive relationship existing between Prolactin and anxiety (Jeffcoate et al,1986).

Klein et al (2001) found that free T4 negatively correlated significantly with IQ in the 172 children using bivariate regression analyses (p-value

= 0.039). Female students with low T4 had more math attention than those with high level of the hormone. This can be explained in accordance with the results published by Klien et al that low level of T4 in students results in higher IQ.

Researchers should note that Because of lack of evidence about the relationship between these factors and different hormones, the comparison of the result of this study to other research summarized to what they said in above paragraphs.

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 predictive factors of mathematical performance. 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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