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# The Effects of Sleep Duration on Predictive Factors of Mathematical Performance

Saeed Daneshamooz, Farzad Radmehr, Hassan Alamolhodaei, Masoome Mohajer
School of Mathematical Sciences-Ferdowsi University of Mashhad

## ABSTRACT

Research in the area of sleep problems and children is a relatively new field. There is even less research when it comes to examining the issue of sleep problems and the effect it has on academic performance. The main aim of the present study is to discuss the relationship between sleep duration, mathematical performance and its predictors. A sample 150 secondary school girls were tested on (1) the Witkin's cognitive style (Group Embedded Figure Test) (2) Digit Span Backward Test (3) Mathematics Attention Test (4) Modified Fennema-Sherman Attitude Scales (5)Mathematics Anxiety Rating Scale and math exams. Results obtained indicate that students with 7-8 hours of sleep duration had better performance in mathematical activity and math score. In this study in term of sleep duration no significant difference found for predictive factors of mathematical performance. But some non-significant differences between predictive factors of mathematical performance and sleep duration were found.

**Keywords:** *Mathematical performance-Sleep duration-Predictive factors*

## 1. INTRODUCTION

Research in the area of sleep problems and children is a relatively new field. There is even less research when it comes to examining the issue of sleep problems and their effects on academic performance. A child who is struggling in school may be dealing with the effects of poor or inadequate sleep, rather than a lack of ability. Studies suggest that adolescents who get an optimal amount of sleep report higher grades than their sleepy counterparts [1-4]. Research studies concerning sleep deprivation have found that lack of sleep has strong ties to several factors that could potentially affect academic success, especially at the college level. Lack of sleep can adversely affect functions of the frontal cortex of the brain, and implicit learning has been associated with the prefrontal cortex of the brain [2]. In addition, those learners labeled as having attentional issues may also be experiencing the effects of poor sleep [4]. Concern to mathematical performance, Ng et al.[5] found that Mathematical performance was positively correlated with sleep duration. Excessive sleepiness on rising was identified as a significant risk factor for poor performance in Mathematics.

Neurobiological theories propose that every part of the body, down to the smallest cell, is involved with the process of sleep. Sleep gives the brain time to integrate and process the information learned during the day. The process of sleep is so necessary for daily functioning that extended sleep deprivation can lead to death. Sleep is so vital to the body's daily functioning that a prolonged loss of sleep impairs metabolism, immune function, temperature control and can ultimately lead to death [4, 6].

The amount of sleep required decreases as an individual age. The average infant sleeps approximately 16 hours a day, and by one year of age sleeps approximately 11 hours with an additional 2.5 hours of naps. An average 3 year-old gets 10.5 hours of sleep with a 1.5 hour nap. By age 18, total sleep has decreased to approximately 8 hours [7].

### 1.1 Mathematical Problem Solving

Over 60 years ago, the importance of problem solving was recognized and its importance was emphasized strongly throughout the 1980s [8]. NCTM asserted that problem solving "should be the central focus of the mathematics curriculum" [9] and Polya [10] and others (e.g., [11]) maintain that problem solving is the goal of mathematics learning. More recently the NCTM reiterated its call for problem solving to form an integral part of the mathematics curriculum [12].

According the importance of math problem solving the present study was carried out by the authors to study mathematical problem solving in term of sleep duration. In this study the relationship between sleep duration at afternoon and night and predictive factors of mathematical performance (i.e. mathematics attention, attitude, anxiety, working memory capacity and filed dependency) will be discussed. It seems to be more beneficial to describe the historical background of predictive factors of mathematical performance before introducing research framework.

### 1.2 Working Memory Capacity and Mathematical problem solving

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:[13]):As Baddeley [14,15] 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[14] model of working memory has been particularly useful in explaining a variety of thinking phenomena [16].

Working memory capacity (WMC) is essential for important cognitive abilities including reasoning, comprehension and problem solving [17]. 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 [17, 18].

There are some considerable evidences suggesting that WM may be important for mathematics learning and problem solving. For instance, Adams and Hitch [19] 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 [19-21].Moreover, Alamolhodaei [22,23] have found that the students with high WMC, are more capable of solving math word problems compared to those with low WMC .

## 1.3 Cognitive Style (Field Dependency)

Cognitive style differences influence the acquisitioned 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 [24].

Several researchers have demonstrated the importance of field dependency in science education and mathematical problem solving, in particular word problems [22,25-31]. 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.

## 1.4 Math Attitude

Many researchers report that positive mathematical beliefs, attitudes, and feelings will lead to increased mathematical achievement [32-34]. Attitudes towards mathematics appear 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 [35, 36]. Negative attitudes and emotions, together with inadequate self regulatory behaviors, are often connected with students' preventive beliefs and perceptions in mathematics learning situations [37-39]. Such beliefs and behaviors derive from students' previous classroom experiences, both positive and negative; they are highly stable and difficult to change (e.g., [40,41]).

## 1.5 Math 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 [22,42-45]. It has been directly or indirectly, affecting all aspects of mathematics education as one of the most commonly investigated constructs in mathematics education [46]. In fact, math anxiety may be defined as a feeling of tension, apprehension, or fear that interferes with math performance [47]. 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 [22, 42, 48-53]

## 1.6 Math 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 [54]. There has been demonstrated a close relation between attention and memory in the limit capacity system [55]. 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 [54,55].

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, [56] 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 meaningful 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 [57].

According to Alamolhodaei, Farsad and Radmehr [58] math attention has the highest path

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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.

## 1.7 Research Framework

The main aim of the present study is to investigate the relationship between each of predictive factors of mathematical performance and k-7 students' sleep duration. Thus the main question addressed here is: Is there any relationship between sleep duration and predictive factors of mathematical performance? In an attempt to answer this question the following objectives were sought:

The first objective of the study was to discover whether in which group of sleep duration, students have the highest mathematical problem solving in final exams.

The second objective of the study was to find whether in which group of sleep duration, students have the highest mathematical performance in math classroom's activities.

The third objective of the study was to determine in which group of sleep duration, students have the lowest mathematical anxiety.

The fourth objective of this study was to find out student with higher working memory capacity was placed in which group of sleep duration.

The fifth objective of this study was to discover whether in which group of sleep duration, students have the highest positive attitude toward mathematics.

The sixth objective of this research was to determine in which group of sleep duration, the score of students' cognitive style test was higher.

And the last objective of this research was to find out in which group of sleep duration, students have the highest math attention.

## 2. MATERIALS AND METHODS

## 2.1 Participants

The sample group of the present study comprises 150 school girls (aged 13–14 years old) who were selected from seven classes of three secondary (guidance) schools of Mashhad (Khorasan Razavi Province). For this purpose, random multistage stratfied sampling design was used.

## 2.2 Instruments

The research instruments were:

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)

Also students' final math score and average score of their mathematical activity in the classroom was gathered from the schools. These scores were estimated from 40. For measuring sleep duration, an answer sheet was completed by their parents for 14 days of their children's' sleep in afternoon and night.

## 2.3 Digit Span Backwards Test (DBT)

For measuring students' working memory capacity (WMC), DBT has been showed to be the most suitable test [22, 26, 53, 59]. 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 five plus or minus two storage unit as Pascual Leoni described.

## 2.4 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. The MARS for this research was newly designed by the researcher according to the inventory test of Ferguson [60]. 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 afive 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.

## 2.5 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) [61]. In this test, subjects are required to dissemble 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 [22, 28, 59].

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## 2.6 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 the URL given below: URL: http://www.woodrow.org/teachers/math/gender/08scale.html

## 2.7 Mathematics Attention Test (MAT)

The level of math attention was determined by an unpublished attention test which has been developed in the Faculty 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?

| Q/NO | Questions |
|---|---|
| 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 too abstract and you have no idea about it in your mind. |

## 3. RESULTS

WMC, GEFT score, Math attention, attitude and anxiety should be correlated to mathematical problem solving according to research literature. Concern to Table.1, significant correlation between these factors and mathematical performance was obtained. Students' mathematical problem solving (math score) was positively correlated with WMC, GEFT score and attitude towards mathematics at 0.01 levels. Also positive significant correlation between Students' mathematical problem solving and mathematics attention was found at 0.05 levels. In addition the Pearson's correlation between students mathematical problem solving and mathematics anxiety was negatively significant at 0.05 levels. In addition for mathematical activity in the math classes same results obtained in this study.

**Table 1:** Correlation of mathematical performance and predictive factors

| | Mathematical Activity | Math Score | Working Memory Capacity | Field Dependency | Math Attention | Math Attitude | Math Anxiety |
|---|---|---|---|---|---|---|---|
| **Mathematical Activity** | 1 | | | | | | |
| **Math Score** | .978** | 1 | | | | | |
| **Working Memory Capacity** | .348** | .342** | 1 | | | | |
| **Field Dependency** | .536** | .498** | .334** | 1 | | | |
| **Math Attention** | .231* | .205* | .352** | .301* | 1 | | |
| **Math Attitude** | .369** | .348** | .338** | .172 | .549** | 1 | |
| **Math Anxiety** | -.208* | -.200* | -.323** | -.341** | -.430** | -.448** | 1 |

** Correlation is significant at the 0.01 level * Correlation is significant at the 0.05 level

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Students' sleep durations in afternoon and night for 14 days was gathered and students were classified in four groups as shown in Table 2 .Kruskal–Wallis one-way analysis of variance found no significant relationship between sleep duration in four groups and students' mathematical activity, math score ,WMC,GEFT score, math attention, anxiety and attitude according to Table 3. While according to Table 2 in group which students have 7 to 8 hours sleep per day have better mathematical activity and math score than others. Also students who have the superior WMC and better achievement in GEFT exam were placed in this group according to Table 2.In addition, this group has less math anxiety than others and their attitude toward mathematics was more positive in this sample. Concerning to mathematics attention, the attention of all groups was close although the superior was achieved by the second group.

**Table 2:** Mean and SDs of sleep duration & Predictive factors of Mathematical Performance

| **Sleep Duration** | **Mathematical Activity** | | **Math Score** | | **Working Memory Capacity** | | **Field Dependency** | | **Math Attention** | | **Math Attitude** | | **Math Anxiety** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **6-7 hours(Group 1)** | 30.4 | 5.81 | 33.60 | 4.45 | 4.20 | 1.09 | 3.50 | 2.38 | 77 | 7.24 | 171.67 | 16.86 | 98.80 | 9.98 |
| **7-8 hours(Group 2)** | 35.71 | 4.16 | 37.82 | 2.63 | 4.44 | 1.29 | 4.65 | 2.23 | 79.75 | 12.08 | 179.85 | 24.73 | 91.59 | 24.54 |
| **8-9 hours(Group 3)** | 31.26 | 6.77 | 34.40 | 5.81 | 3.85 | 1.22 | 3.83 | 3.25 | 76.54 | 10.09 | 172.73 | 20.45 | 97.47 | 16.14 |
| **More Than 9 houres(Group 4)** | 31.08 | 7.94 | 34.02 | 6.92 | 4.03 | 1.31 | 3.26 | 3.09 | 79.67 | 9.62 | 172.69 | 19.01 | 94.45 | 16.77 |

**Table 3:** P-values of Sleep duration & Predictive factors of Mathematical Performance

| | **Mathematical Activity** | **Math Score** | **Working Memory Capacity** | **Field Dependency** | **Math Attention** | **Math Attitude** | **Math Anxiety** |
|---|---|---|---|---|---|---|---|
| **P-Value** | .158 | .285 | .398 | .499 | .478 | .655 | .773 |

Since, the second group has better performance in mathematics and its predictors, in this part of results, students' performance in this group has been compared to others group individually.

Man-Whitney U Test found significant difference between students' mathematical activity and sleep duration in group 1 and 2 according to Table 4. In other words students placed in group 2 had better performance than students in group 1.For group 3 and 4, same results obtained regarding the superior of group 2 with these P-Values .034, .087 respectively. Researchers should note that the difference of students' mathematical performance between group 2and 4 was significant at .01 level.

According to Table 4 significant difference between students' math score and sleep duration was obtained in group 1 and 2 at .05 levels and in group 2 and 3 at .01 levels regarding the superior of group 2.Concern to WMC, significant difference between group 2 and 4 obtained in terms of WMC at .01 levels according to Table 4.It means that Students who have placed in group 3 significantly have lower WMC than students in group 2.For other groups no significant difference between sleep duration and WMC has been reported. For other psychological factors that attribute to mathematical performance, no significant differences were found between them and sleep duration that shown in Table 4.

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**Table 4:** Comparing Group 2 with Other Groups In terms Of Mathematical Performance and its Predictors.

| | Mathematical Activity | Math Score | Working Memory Capacity | Field Dependency | Math Attention | Math Attitude | Math Anxiety |
|---|---|---|---|---|---|---|---|
| **6-7 hours** | .047 | .034 | .484 | .391 | .985 | .637 | .410 |
| **8-9 hours** | .034 | .093 | .095 | .127 | .464 | .250 | .669 |
| **More Than 9 hours** | .087 | .202 | .181 | .283 | .681 | .341 | .984 |

## 4. DISCUSSION

According to results of this study, mathematical performance can be predicted by some psychological factors like WMC, GEFT score, math anxiety, attitude and attention. Findings of this study support previous claims that these psychological factors could predict mathematical performance (e.g., [22, 53, 62], for WMC,[22, 24, 26], for GEFT score, [36, 63] for math attitude,[22,42,43], for math anxiety , [58, 64] for math attention).Also many studies investigate the relationship between sleep duration and academic performance specially in mathematics[5, 65] but a few studies concern to predictors of mathematical performance like math anxiety , attitude towards mathematics and etc.

This study showed that students in group 2 had significantly better mathematical activity in the math classes than other groups. This finding support this fact that students with sleep deprivation (group1) has lower mathematical performance than students with normal sleep duration [5].Although studies showed that normal sleep duration for adolescent is 8 1/2 to 9 1/4 [66].So student who placed in group 3 had normal sleep duration but Learners who placed in group 2shown better performance in mathematical activity and math score. This happened because maybe these students had more times to spend for studying their lessons and doing their math homework. George et,al [66] found that time studying is one of the predictors of GPA. Students in these ages spend many times on playing PC games, watching TV and surfing the Internet. So they don’t pay enough attentions on their math homework and their lessons. Also researchers should note that there is not a large gap between the sleep duration of group 2 and 3. Therefore students in group 2 maybe hadn’t catch sleep deprivation and this time of sleep is enough for their health.

Another finding of this study is that students in group 2 had more positive attitude towards mathematics, more math attention, less mathematics anxiety, higher WMC and GEFT score than other groups in this study. This Superiority wasn’t significant but it was exist and could led students in the group 2 to perform better in mathematical task. Also researchers should note that the group of students which have better performance in mathematical task and its predictors may be different in other levels (e.g., primary school, high school and college). Therefore we should encourage other researchers in this field to study sleep duration of students in terms of predictor factors of mathematical performance in larger samples and in other levels of mathematics to study the relationship between mathematical performances, its predictors and sleep duration more deeply.

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