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The Effect of Explicit and Implicit Instructions and Sleep on Consolidation of the Accuracy of Elements of a Fine Motor Skill

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Two processes are suggested for intervention in the learning of motor skills. These include explicit process in which the performer consciously knows the acquisition of the skill and the other one is an implicit process in which the performer has no conscious knowledge of acquiring the skill. The purpose of this study was to investigate the effect of explicit and implicit instructions and sleep on the performance of the fine motor skill. Participants in this study included 30 right-handed volunteer students with a good sleep quality, aged between 18-25 years old. They were randomly divided into two homogeneous explicit (N = 15) and implicit (N = 15) groups based on Purdue Fine Motor Skill Test and Simple Reaction Time. Each group participated in a three-time round at six in the afternoon, 12 midday on the same day, and at eight o'clock next morning in a Timed Motor Sequences Task. The data was analyzed by ANOVA with repeated measures. The results showed that in the accuracy of the short elements, stabilization was done but promotion was not observed but there was no change in the accuracy of the long elements and there was no significant difference between groups.

Keywords: Accuracy; Explicit and Implicit Learning Instructions; Fine Motor Skill; Nighttime Sleep.

Learning motor skills, as learning skillful behaviors, includes different areas in which the first part involve learning a series of events or changes that occur during training sessions, enabling a person to perform a task skillfully (acquisition stage). In other words, acquisition of motor skills is a process in which a person enhances a set of motor responses to an integrated and organized movement model during a training session[1].

Lemieux & Penhune (2005) pointed out three stages of learning motor skills in their study and stated that the first stage occurs at the first session of the practice, during which rapid recovery is observed. The second stage refers to consolidation that occurs after the first training session. In consolidation, significant improvement is observed in the performance following a rest period of more than four hours. In addition, it has been shown that night sleep improves the performance of newly acquired skills. The third stage of learning motor skills occurs during the remaining training sessions (days or weeks) where gradual and slow progress leads to stability[2].

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Based on the consolidation theory put forward by Muller and Pilzecker (1900), information is stored in the form of a dynamic electrical activity and is gradually transformed into structural changes in the brain. Accordingly, in the pursuit of learning experience, a continuous process takes place in a variety of stages, until the memory works are fully consolidated or stored in the form of structural or chemical changes[3]. Conversely, memory consolidation refers to processes of the reactionary nature of the brain, whereby those experiences tend to lead to sustained changes in adaptive behaviors[4, 5].

Studies have shown that it is not just a repetition of training to guarantee the acquisition of a motor skill, but the improvement of memory depends on the processing of information at a deep level (Krick 1971, Krick and Kelhart, 1972). This view suggests that repetition only improves memory once the learning materials are deeply and meaningfully reviewed. Discontinued repetition does not result in memory improvement[6].

Karni *et al.* (1994) and Walker *et al.* (2002) argued that the process of memory consolidation as a result of the time passed (awakening and sleep) and in the absence of practice, would develop skills[6, 7].

Walker (2005) classified the process of consolidation into two stages of stabilization and enhancement, in a new model that refines and completes the classical model of procedural memory formation. Stabilization refers to maintaining the level of practice skills relative to the end of the first practice session, in the absence of further training. It starts at the first training session and lasts for about six hours during the awakening. Consolidation refers to advancements in the performance of motor skills relative to the end of the first practice session, in the absence of further practice, during sleep and at or after the end of the stabilization phase[7].

In motor skills, the practice of a motor task results in the production of an internal model that indicates different motor outputs in response to different stimuli of the task. The development of the internal pattern does not end when the practice ends. However, it continues for several hours, during which the memory paths of that model are strengthened, for example, it is increasingly resist to behavioral interactions. More importantly, the internal model in this process becomes more efficient. This performance is determined by the various performance improvements performed in the 24-hours retention test [6].

Brain does not stop processing information when the practice is interrupted[8]. Given that physiological changes occur in the brain during sleep, the notion that brain is not active during this time is incorrect[9]. Sleeping as an event that a person encounters in his or her environment has a very important biological function[10].

Hall (2015) states that during each night, there are two types of sleep that occur in a relationship between each other: 1. Sleep with Slow Waves (SWS) and sleep with Rapid Eye Movements (REM) (11). One of the important features of REM sleep is that the brain is very active during this sleep and overall brain metabolism may increase by 30%. In summary, REM is a dream in which the brain is fully active[11].

It is believed that consolidation of memory is benefited from sleep. Studies showed that increasing the contribution of the REM sleep stage after confronting learning situations leads to better learning. So, good night sleep with enough REM seems to help with memory consolidation[12].

The studies on animals and humans state that brain plays an important role in the formation of memory and learning in the sleep state[13]. For example, sleep improves procedural memory (executive) and learning of motor skills[13-16].

Research results in visual tests, motor sequencing, and motor matching showed that post-training consolidation occurred after night sleep; however, no consolidation was observed in the same period of time and in awakening. Also, the results indicated that one night consolidation was associated with a specific amount of sleep, or sleep related events, and a partial or total consolidation of sleep, which could prevent consolidation throughout the night[17].

Research has shown that if sleep (day or night) is of adequate depth and duration, including both the SWS and REM sleep stages, it can consolidate a procedural skill[21, 22]. Studies have shown that the most delayed consolidation in execution is after the first night of sleep after exercise at the acquisition stage, and the sleep of the next nights leads to a smaller consolidation[5, 21, 23, and 24]. It seems that the first night of sleep after the first training session has led to a consolidation of 12% to 30% in performing assignments such as drawing in the mirror, the sequence of motion of the fingers[7, 12, 23, and 25]. In this regard, Lemieux *et al*. (2005) evaluated the components of accuracy, timing and stability in a Timed Motor Sequences Task (TMST), and stated that after the first night of sleep, significant improvements were observed in the components of accuracy, timing and sustainability[24]. Walker *et al*., and Fischer and colleagues (2002) also investigated the accuracy and speed of performance in fingerprint assignments and thumb handling with fingers. The results showed that the first night of sleep after the first training session could significantly improve speed (20%) and accuracy (39%) in fingertip assignment and run speed (33.5%) and accuracy (30.1%) in the task of thumbs coping with fingers[12, 23].

Therefore, if we accept that acquiring a new skill is the beginning of the process of memory formation, consolidation of unstructured memory as a process of silent consolidation that occurs between two sessions of practice can also play an important role in improving the skill[8].

The teaching of motor skills to athletes has always been the main task of sports educators and physical education teachers, and a bulk of studies in motor learning have always sought to discover better ways to help learn skills[10].

There are many ways to learn motor skills, some are called explicit learning methods, and some are classified as implicit learning methods. Explicit learning involves processes in which problem solving is deliberately performed, and a conscious effort is done based on organizing the assignment, directing memory search for similar or contradictory information related the task structures[18].

In the definition of implicit learning, Reber (1967) states that it involves the acquisition of knowledge independent of the conscious pursuit of learning in the absence of explicit knowledge and about what has been acquired[18].

Research have shown different effects in these two types of explicit and implicit practices. Some researchers believe that explicit knowledge processing in working memory and accumulation of declarative knowledge in the early stages of learning is an essential part of performance and motor learning[19, 20]. In the training of motor skills in the conventional way, information about the performance of the movement is presented explicitly through the display, illustration, feedback and verbal guidance to the performer, and it is assumed that these tutorials will help the learning process. In explicit learning, people are consciously learning knowledge of task rules, so for this type of learning, conscious attention and the use of working memory is essential[21]. The practice of a step-by-step instruction during an obvious learning process brings the learner to a set of knowledge about learning skills and, according to this, the learner learns and implements skills. Just like when a beginner is practicing a badminton service, he/she can review the ball throwing and hands movement for themselves[19, 22].

In contrast, some scholars have argued that the lack of explicit knowledge about the underlying mechanics of motor skills does not harm learning and even improves performance through psychological pressure[23].

In the field of rehabilitation, Ehsani *et al*. (2012), considering the importance of performing motor skills and learning these skills in the elderly, in an analytical and comparative study to examine the effect of explicit knowledge on learning, examined a serial reaction time task (SRTT) and concluded that much awareness and explanation before starting rehabilitation and acquiring skills in the elderly not only had no effect on the level of learning and acquisition of skills, but also had a negative effect on the learning of these individuals and reduced the learning ability of the elderly, which is important in the designing of rehabilitation protocol of elderly people[24].

Also, Talim Khani *et al* (2014) conducted a systematic study of past studies to investigate motor learning in patients with unilateral brain stroke and concluded that the ability for the implicit motor learning of unilateral brain stroke patients is still maintained if their motor tasks, the corresponding type of feedback, and explicit training to the patient is in the way that it does not increase the need for motor memory or the severity of stroke is low[25].

The type of the task is also one of the factors that affects the acquisition of motor skills[4]. Recent evidence suggests that although the first night of sleep improves a number of motor tasks, it may not be beneficial for all types of tasks. Song *et al*. (2007), using a probabilistic motor sequence learning, showed that this type of task was not consolidated with the first night of sleep after the first training session[26]. In their research, Brown *et al*. (2010) used a motion sequencing task and found that performing a motion sequencing during awakening was corrupted after the first training session and was retrieved after sleep, without further consolidation from the initial performance level[27]. In their study, Wilhelm *et al*. (2008) used a fingertip assignment in children and showed that the first night of sleep does not have an effect on the consolidation of the memory of children and only improves their declarative memory (28). Shahabi and colleagues (2014) evaluated the effects of practice and nighttime practice on consolidating the components of "accuracy" and "timing" of fine motor skills. The results showed that the first night sleep after a training session did not improve the accuracy of these elements.

Therefore, it seems that the effect of the first night of sleep on improving the performance of motor tasks depends on the nature and type of its components. One of the objectives of this research is to answer the question whether the explicit and implicit learning instructions and the first night of sleep after the training session consolidates and improves the "accuracy" component in a scheduled sequential motion assignment or not.

MATERIALS AND METHOD

Participants

The participants included 30 right-handed male students who had no history of neurological disease and were not continuously active in fields that classified as hand-fingers, such as typing and playing piano. They had a good sleep quality.

Instrument

Sleep quality questionnaire (The Pittsburgh Sleep Quality Index, 1989): The purpose of this test was to measure the quality of sleep during the past month, which consists of seven sub-scales. The reliability of this questionnaire was 0.83 using Cronbach's alpha coefficient[29].

Purdue Fine motor skill test of hand and fingers

Purdue Pegboard measures two types of skills (agility): 1) movements that involve hands, arms, and fingers; 2) fingertip agility. This test consists of four sub-tests: right handed, left handed, dexterity, and upright. The reliability of this test in 2005 for the age range of 15 to 25 years old for men and women in right handed subtest was 70% and 82%, respectively, and the validity of the test was reported to be 91%[30].

Reaction Time Measurement

To measure the reaction time, SUPER LAB 4(Cedrus Corporation, USA) was used which was designed to measure cognitive and motor skills and measure these skills up to a thousandth of a second[31].

Timed Motor Sequences Tasks (TMST)

This task consists of 18 elements (six elements of the middle section, six elements of the first section, and six elements of the last section, in which the layout of the elements of each section was available to the researcher), which was visualized with a length of 1400 milliseconds for long elements and 700 milliseconds were provided for short elements, and the interval between each element was considered to be 500 milliseconds. The elements appeared in a sequence at intervals of 0.500 seconds in the middle of the screen. The accuracy of the response (the percentage of correct answers for short and long elements) in the main task was calculated through the calculation of the average responses for short and long elements 1 ± SD in the basic tasks. Considering this range as the correct answers for the short and long elements in the main task was measured and then the percentage of correct answers for the short and long elements in each effort category was calculated. The accuracy of the response is improved when its value increases. Participants completed a total of 162 trails in three-stage blocks.

This task was first created by Penhune and Diven (2002). It includes 10 short and long elements. This software was again prepared by Shahabi *et al*. (2015) after considering changes to facilitate implementation, calculations, variation in the layout and scheduling of the elements while maintaining the main features.

Procedure

Eligible participants were divided into two groups of homogeneous. The two groups had to practice a timed motor sequences task in two different learning conditions. Participants had to press and hold the key with the right mouse button and each element would be visible and click on the key to see the end of the element. At the beginning of each session, the participants completed the basic tasks in three blocks of 18 trails (total=54 trails), and then, practiced the main task in three blocks of 54 trails (total=162 trails). After each main task, the participants received the external feedback (average) on the accuracy of the response. In order to investigate the difference between different learning conditions, the accuracy components were evaluated at three times at 18:00 and 24:00 of the same day, and 8:00 am (after night sleep). To analyzing data, the mixed ANOVA with repeated measures was used (± = 0.05).

RESULTS AND DISCUSSION

The purpose of this study was to investigate the effect of explicit and implicit instructions and night sleep on the consolidation of accuracy in a fine motor skill. Consolidation has two components: Stabilization and Enhancement. Therefore, the results and discussion have been also followed respectively.

As shown in Table 1, the effect of time and effect of interaction of time × groups on short and long elements is not significant (p> 0.05).

As shown in Table 2, the effect of time and effect of interaction of time × groups on short and long elements is not significant (p> 0.05).

The effect of explicit and implicit instructions and night sleep on the stabilization of the accuracy of short and long elements

The results showed that stabilization has been made in the accuracy of short elements, but in the accuracy of the long element, stabilization has not been established.

As Afen-noy (2003) states that even a single repetition can lead to consolidation and memory retrieval, the stabilization was also needed in long elements; however, considering that in the present study, stabilization occurred only in the accuracy of the short elements, it seems that a factor such as the duration of the task execution is a major factor in the stabilization of memory. It seems that in long elements, due to its time attributes which take twice as short elements, a controlled cognitive scheduling system would probably be responsible for measuring the motor timing which needs more explicit attention.

Perhaps, if long elements were practiced more than short elements, stabilization would also occur, in other words, the long elements needed for stabilization would probably need to be repeated more precisely.

In the context of the repeat susceptibility process, Ofen-noy (2003) suggests that the repetition counter may be a critical trigger for the effective formation of procedural memory and

Table 1. Results of the mixed ANOVA (2 × 2) to stabilization of the accuracy of the short and long elements

Type of elements	effect	Value	F	sig	Partial eta squared
Short elements	time	0.991	0.218	0.645	0.009
	time*group	0.951	1.30	0.265	0.049
Long elements	time	0.951	1.27	0.269	0.049
	time*group	0.999	0.017	0.898	0.001

Table 2. Results of the mixed variance analysisANOVA (2 × 2) to enhancement of the accuracy of short and long elements

Type of elements	effect	Value	F	sig	Partial eta squared
Short elements	time	0.988	0.313	0.581	0.012
	time*group	1	0.002	0.967	0.001
Long elements	time	0.857	4.16	0.052	0.143
	time*group	0.999	0.016	0.9	0.001

some informative memory and is triggered by a certain number of repetitions. Therefore, it should be repeated in long elements to repeat the trigger[6].

Also, there was no significant difference between the effects of two types of instructions in stabilizing the accuracy component in this task. In this regard, the results of the research are in line with the results of the study conducted by Kheirandish *et al*. (2009) who confirmed the results of the implicit learning effectiveness as much as that of the explicit learning[32]. Furthermore, it is in line with the results of the study by Farnaghi *et al*. (2015) who stated that there is no difference between the explicit and implicit training in the accuracy of the sequential reaction[33]. Possibly the nature of the task is such that it is possible for the implicit group to have inferred its own task, despite the information provided to the explicit group. In other words, the nature of the task in the current study seems to be that the giving of the instruction is not very important for implementation, and if the information is not given, it would be possible to obtain the information necessary for the optimal implementation of the individual from the domain of execution. It is also possible that the number of repetitions was so large that, despite the decrease by the researcher, this number of repetition exercises was not able to provide the necessary information about the order of the appearance of the elements and the time it takes for the implicit group.

The effect of explicit and implicit instructions and night sleep on the enhancement of the accuracy of short and long elements

The findings of this study showed that the first night of sleep after a training session caused a significant improvement in the accuracy of the short and long elements, and there was no decrease in the accuracy of the performance. Therefore, the findings of the present study are consistent with the results of studies by Song *et al*. (2007), who stated that there was no significant enhancement in the accuracy of first night of sleep performance in the probabilistic motor sequence task[26], and also with the results of Shahabi K. *et al* (2013) stating that after the first night of sleep, no significant enhancement was observed in the accuracy of the movements performed (10). The results of this study were also consistent with the findings of Brown *et al*. (2010), who stated that the accuracy of the execution significantly decreased after training during the day; however, after the first night of sleep, this reduction was compensated and retrieved. In other words, night sleep does not improve motor sequencing beyond the level of execution achieved after training[32]. Also, the results are consistent with the findings of Shahabi *et al*. (2014) who stated that the first night of sleep after a training session (noon, evening, and night) did not significantly improve the accuracy of short and long elements, and no decrease was observed in the accuracy of the execution[10]. Also, the results are consistent with those of Walker *et al*. (2002) finding that the first night of sleep increases the speed of movement without decreasing accuracy in a fingertip tapping task[15].

On the other hand, the findings of this study on the accuracy of the response is not in line with those of the study by Walker model (2005), which stated that the performance of a motor task is improved after the first night of sleep; therefore, it seems that one night of sleep enhances certain components of motor skills with special features. The results of this study were compared with the results of Lemieux & Penhune (2005), who assessed the accuracy component of the response in the timed motor sequence task (TMST), and showed that after the first night of sleep, a significant improvement in the accuracy component occurred[2]. Perhaps the reason for this discrepancy can be attributed to the methods of measuring the accuracy component in these two studies. In their research, the required limit for the correctness and incorrectness of the short and long elements in TMST task was the mean of short and long elements in the basic task ± 2 standard deviation[2]; however, in the present study, for more precise measurement, this limit was reduced to ± 1 standard deviation. Obviously, the threshold of ± 2 standard deviation (about 95% of the surface under the standard curve) than ± 1 (about 68% of the surface under the standard curve) in the base task provides a larger scope for the correct response to the TMST task. Therefore, in the study by Lemieux & Penhune (2005), if the test user has not made much error in response to short and long elements, his response is likely to be in the 95% range, which reduces the measurement accuracy. Also, in their research, the accuracy component is calculated in general and based on the average of the short and long elements, which makes the effect of a sleep night on the accuracy of the short and long elements, separately and correctly, but in the present study, the accuracy component of short and long elements is calculated individually, which increases the measurement accuracy. The other thing is that, in their study, only compared the results of the first and second day without comparing the basic tasks. This is one of the factors that can cause errors in measurement [10], because the participants on the second day may have shown greater accuracy in the main test than the first day, but the average of the short and long elements in the basic task may have increased on the second day than the first day which can increase the range desired for the correctness and incorrectness of the elements numerically on the second day. However, in the present study, the basic tasks in the first and second days were compared with each other where no significant differences were observed. Another reason for the discrepancy of the present study with Lemieux & Penhune (2005) is that in their research, the last block of the first day was compared with the first block of the second day, each block comprising 120 attempts (2, 10). According to Vertes and Eastman (2000), it seems that due to the high number of attempts, enhancement appears to be due to the effect of the practice rather than the effect of night sleep (34). In the present study, 10 attempts at the end of the first day and 10 first attempts of the second day were compared, which would minimize the effect of the workout and make the night sleep effect clearer. The results of this study also examined the results of Walker *et al*. (2003, a, b) and Fischer and colleagues (2002) who studied sleep-related motor skills learning using sequential fingertip tapping task and stated that the first night of sleep leads to enhance the accuracy of motion[13, 35, 36].

Finally, the results of this study were inconsistent with the results of Robertson *et al*. (2004) who showed that awareness is an important factor in offline learning. When a person is aware of the features of the new skill that wants to learn, he or she will show more progress in skills, without practicing under the influence of sleep. Conversely, when a skill is learned with little awareness, skill development is not affected by sleep[37]. Since, in this study, accuracy was considered as an explicit component in the TMST task for measuring explicit knowledge of the arrangement of short and long elements in sequence[2], according to Robertson *et al*. (2004), after the first night of sleep, an enhancement in the accuracy of the performance should be observed [37]; however, the results of the present study are not in line with this notion. Perhaps the reason for this contradiction can be attributed to training conditions, measurement methods, type of task, and the nature of its components. As it seems, the accuracy component for consolidation in memory is not simply affected by nighttime sleep. Future research is needed for more information in this regard. Moreover, there was no significant difference between the effect of two types of explicit and implicit instructions on the accuracy component of this task.

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