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The Effect of Different Ages levels and explicit - implicit Knowledge on Motor Sequence Learning

Sayed Kavos Salehi, Mahmood Sheikh, Rasoul Hemayattalab, and Davod Humaneyan

Department of Motor Behavior, School of Physical Education and Sport Sciences, University of Tehran, Tehran, Iran

ABSTRACT

This study aimed to investigate the effect of different Ages levels or age-related changes and explicit and implicit knowledge on mixed motor sequence learning and its consolidation. In this study, 96 right-handed boys who were healthy considering nervous system with age range of 6-18 years were selected via convenience sampling method. Serial reaction time task (SRTT) was used to evaluate and compare the performance in two components of response time and accuracy. The intervention was consisted of 10 stages (8 blocks for acquisition and 2 blocks for consolidation) in which the performances of groups were compared. The data were analyzed using mixed ANOVA test in 2 (type of learning) × 4 (age groups) × 8 (blocks) and Bonferroni test was used for paired comparisons. In acquisition phase for response time, significant main effects were observed for block ($P = 0.031$) and age ($P = 0.001$), not learning conditions ($P = 0.431$). For response accuracy, significant main effects were observed for block ($P = 0.001$), age ($P = 0.001$) and learning conditions ($P = 0.003$). In addition, the performances of groups across the two first blocks of practice on the second day were better compared with the first day in response time ($P = 0.001$) and accuracy ($P = 0.001$), which represented the consolidation of motor learning. The findings showed that among different age groups, there were age-related functional changes in the acquisition and consolidation of response time and accuracy for motor sequence task. Moreover, the various components of the movement (speed and accuracy) can be performed and consolidated in different ways. This matter should be considered in educational and rehabilitation interventions related to children and adolescents.

KEYWORDS
Explicit learning, Implicit learning, Age-related changes, Learning consolidation, Performance

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CORRESPONDENCE Sayed Kavos Salehi Sk.salehi@yahoo.com

Introduction

One aspect that is important in instruction and rehabilitation training is learning of related behaviors arising from the movement. Movement is taken into account basic aspect of human development and the best justification for studying the movement is that the movement is the main component of human development (Schmidt RA & Lee, 2011). Some kinds of movements such as walking and blinking, are self - differentiated or phylogeny that in this movements, the pattern of the action is determined through genetics, development or both of these cases. The second group of movements are learnable movements such as typing and shooting that proficiency in them requires experience and practice. This kind of movements are known as skill (Savion-Lemieux et al., 2009). Therefore, learning of motor skills is one of the aspects of behavior and external mood of motor development that arises from practice and experience (Gallahue & Ozmun, 2011).

Human motor learning and memory functions (information acquisition) can be divided into at least two broad subsystems, termed explicit and implicit. If the learner is given the necessary information about the purpose and how to perform the desired task, this type of learning is explicit but if is not given the necessary information to the learner, learning will be a kind of implicit (Nejati V et al., 2008). Learning implicitly is characterized by a lack of awareness for the learning process and its content (Cleeremans, 1993; Reber, 1993). In addition, learning the skills not only occur during training (online- phase), but also occurs at intervals of rest between training or in sleep, which are said Offline phase. A process that occur in “off-line” phase is called consolidation (pencer et al., 2007; Izadi-Najafabadi et al., 2015).

Implicit and explicit have fundamental differences in encoding and retrieval mechanisms and are controlled by different neural networks. It is believed the neural network that controls the implicit learning include the basal ganglia, cerebellum and prefrontal cortex, while explicit learning is controlled by temporal lobe, hippocampus, thalamus, and prefrontal - parietal cortex (Thomas & Nelson, 2001). Mostly, the typical behavior that is used to evaluate the functions of implicit and explicit learning is motor sequence learning, because motor sequence con be learned explicitly or implicitly. In explicit motor sequence learning the learner is aware from arrangement of sequence but in implicit one is unaware (Robertson et al., 2004).

A question arising from the research conducted on various learning and memory systems has been how to develop these various forms of cognitive function, and the explicit and implicit processes develop as a unit form or as separate and distinct. Prolonged development of prefrontal cortex systems involved in explicit learning compared to the relatively early maturation of basal ganglia structures involved in implicit learning, is a reason that one might expect implicit function to develop earlier than explicit function (Thomas & Nelson, 2001; Amso & Davidow, 2012). In this case, Reber (1993), proposed the developmental invariance model. According to this model, implicit learning is independent of age, because neural structures involved in implicit learning are evolutionarily more primitive and very soon grow and develop so that during childhood remain relatively the same and without altering, While explicit learning show more developmental changes during the time, because this type of learning involves more cortical structures which continue to develop across childhood and into adolescence. However, developmental neuroimaging studies suggest that, although metabolic rate and myelination of the basal ganglia peak quite early in the first year of life (Chugani et al., 1987; Sidman & Rakic, 1982), developmental changes are still occurring well into early childhood. On this basis, by contrast to the view invariance, age-related changes model in implicit learning is presented. The age-related changes models posit that considerable developmental differences can be observed in implicit learning. Several of these studies found that older children and young adults showed stronger learning effects compared to very young participants (Fletcher, Maybery, & Bennett, 2000; Kirkham et al., 2007; Maybery et al., 1995; Thomas, et al., 2004).

As described above, understanding the separation and distinction between explicit and implicit learning during childhood and the effects of age on these type of learning is still the hot topic of debate among cognitive and developmental scientists. As some studies have shown that the implicit learning of some serial reaction time tasks (SRT) despite increasing in age has been fix and there was no difference in adult learning and young people, on the contrary, some studies have observed age differences in learning of sequential movements (Maybery et al., 1995; Vinter & Perruchet, 2000).

Despite the apparent contradiction regarding the effect of age on motor learning, investigating the matter and additional research is important in order to better understand the development of explicit and implicit processes. In the current study we want to fill this gap using a standard task of SRT that first introduced by Nissen and Bullemer (1987). In particular, the main purpose of this research is to answer the main question that is the motor learning capability is changed when age increases and if these change is made, which type of learning more involved. Is the speed that people can choose movements responses is as function of age in two kind of implicit and explicit learning.

Research Methods

Ninety six right-handed male's subjects between the ages of 6–18 in preschool, elementary school, and high school as the final sample were targeted and availably selected in the current study. The inclusion criteria consisted of being right-handed, neurologically healthy, and without the familiarity and experience with the task. The samples were divided into 4 groups that each of which has two subgroups of 12 subjects (n = 12), including 6-year-olds (implicit and explicit), 8-year-olds (implicit and explicit), 10 years (explicit and implicit), and young adults 15-18 years old (explicit implicit).

For evaluating adolescent samples, the test of Mini Mental State Examination (Folstein, 1975) was used to detect cognitive impairment, General Health Questionnaire (Goldberg, 1979) to determine the general health, and The Edinburgh handedness inventory (Oldfield, 1971) to detect hand preference. For preschoolers and elementary school children, their educational case files was study and the teachers and parents were asked about the general health of children. By this way, children with certain diseases or problem were excluded from the sample.

In current study, we used a version of the SRT task that involving a displaying the four boxes, which were arranged in four location of a computer screen. Corresponding keys on keyboard were defined as response keys for stimuli. Eight stimuli appeared sequentially and participants should response to them by pressing the corresponding keys on the keyboard with their index finger of their right hand as quickly and as accurately as possible. Corresponding keyboard buttons were matched to color choice, for example, “P” for blue, “Q” for yellow, “Z” for green, and “M” for red color. Each session had 10 blocks. Each block contained 10 trials (sequences). Each trial contained eight stimuli which appeared sequentially. Thus providing stimuli in regular sequence included green, blue, yellow, blue, red, yellow, green, yellow and in irregular sequence, stimuli are presented in a random order, which means that the provision of stimuli is determined by software and there is no logical relationship in the order of their appearance. All blocks followed this regular sequence except the five and the sixth block which had irregular or random sequences.

In this study, the intervention involves 10 stages in two phases (acquisition and consolidation) in which the results of the groups were compared. Participants first entered the acquisition phase. This phase consists of 8 blocks (each block consists of 10 trials and each trial includes 8 stimulation) that the appearance of the squares in the first 4 blocks was regular. Then two blocks (5 and 6) were performed in irregular order, and then two other blocks (7 and 8), was presented in regular sequence. Therefore, in this study the mixed motor sequences (the combination of repetitive regular and irregular) were used, because the possibility of explicit knowledge in implicit learning groups become minimized.

In the process of research, carrying out experiments was exactly the same in implicit and explicit learning groups, except that before the test, explicit learning groups receive complete information about the emergence of squares and sequence them, but implicit learning groups were not given any information and were not aware of the sequences, Just they were asked which immediately after observing any square, press the corresponding key with speed and accuracy. It should be noted that prior to practice on the SRT, a block for Familiarization phase was performed by different subjects.

One day (24 hours) after the acquisition phase, the second phase; the measurement of learning consolidation was performed. This phase consists of 2 blocks with the same regular arrangement of the first phase.

The reaction time, errors in response were registered by program. The performance of participants in explicit and implicit sequence learning was monitored by a decrease in reaction time, errors in response by calculating the percentage of correct key presses made for each stimulation, trial and block.

In order to assess learning consolidation, the average response time and the number of correct answers two blocks at the end of the first day (blocks 7 and 8) with first two blocks at the second day (blocks 9, 10) in the groups of implicit and explicit were analyzed. All stages of the study was carried out consistent with Code of Ethics and the considerations related to Tehran University.

Findings

Demographic data for the subjects are presented in Table 1. The results of mixed ANOVA test in 2 (type of learning) × 4 (age groups) × 8 (blocks) for response time component during the acquisition phase showed that there was a significant main effect of Block $F(1.01, 89.21) = 4.75$, $P < 0.05$, such that overall there were significant improvements in performance across all blocks ($P \leq 0.031$). Also, there was a significant main effect of age $F (3.88) = 0.744$, but at this stage not found significant effects for learning conditions and interaction between variables ($P \geq 0.05$). Post hoc analyses revealed that there were significant differences between the eighth and second blocks in all groups ($P <$

0.05), which represents the improvements in performance of all groups. Between groups differences showed that response time for 10-15-year-olds in all blocks was significantly faster than all Child groups ($P = 0.001$). In addition, 10-year-olds were marginally faster than the 6 and 8-year-olds (($P = 0.001$). Also, there was a significant difference between the response time of 6-years, 8-years and 10-years children ($P < 0.05$).

Table 1. Demographic data

Groups		Number	Mean (SD)	maximum	Minimum
6 years	Explicit	12	6.3 (0/66)	6.6	6.0
	Implicit	12	6.4 (0/74)	6.5	6.0
8 years	Explicit	12	8.3 (0/45)	8.3	8.0
	Implicit	12	8.5 (0/65)	8.4	8.8
10 years	Explicit	12	10.2 (0/84)	10.2	10.2
	Implicit	12	10.1 (0/91)	10.4	10
15-18 years	Explicit	12	17.6 (0/74)	18.2	15.0
	Implicit	12	17.4 (0/92)	18.1	15.2

The results of mixed ANOVA test in 2 (type of learning) × 4 (age groups) × 8 (blocks) for response accuracy component, showed that there was a significant main effect of Block $F(486.63, 486.63) = 67.40$, $P = 0.001$, age $F(3.88) = 49.95$, and learning conditions $F(1.88, 1.88) = 33.27$, $P = 0.003$. In addition, interaction effects of variables at this stage was significant ($P < 0.05$), indicating that different age groups during the SRT task, in terms of accuracy in response to stimuli in different blocks, according to type of learning (explicit and implicit) had different performance. Post hoc analyses revealed that there were significant differences between the eighth and second blocks in all groups ($P < 0.05$), which represents the improvements in performance of them. Pairwise comparisons showed that 6-year-olds group (explicit and implicit) were significantly less accurate than all other groups ($P < 0.05$), and 8-year-olds were significantly less accurate than 10-year-olds and adolescents ($P < 0.05$), but Adolescents and 10-year-olds had no significant difference ($P = 0.563$), indicating that by block 8, 10-year-olds reached 15-18 year-olds' level of performance.

When comparing response time the groups across the 2 last blocks of practice on Day 1 and the 2 first blocks on Day 2, results indicated overall consolidation in studied groups, such that overall there were significant improvements across the two blocks of practice $F(1. 88) = 557.46$, $P = 0.001$. There was also a significant main effect of age $F(3. 88) = 437.88$, $P = 0.001$, revealed that adolescents were significantly faster than the two youngest Child groups ($P \leq 0.05$), and 10-year-olds were marginally faster than the 6-year-olds ($P = 0.032$) but not the 8-year-olds ($P = 0.80$), indicating that in consolidation phase, 8-year-olds reached 10-year-olds' level of performance. No significant for learning conditions and interaction between variables (Block × age × learning conditions) was observed ($P = 0.829$).

For response accuracy, when comparing percent correct between the groups across the 2 last blocks of practice on Day 1 and the 2 first blocks on Day 2, results indicated overall consolidation in studied groups, such that overall there were significant improvements across the two blocks of practice $F(1. 88) = 187.82$, $P = 0.001$. There was also a significant main effect of age $F (3. 88) = 18.75$, $P = 0.001$, such that 6-year-olds made significantly more errors than all groups ($P \leq 0.005$), and 8-year-olds made significantly more errors than adolescents ($P = 0.001$). In addition, there was a significant main effect of learning conditions, such that explicit groups were performed more accurate than implicit groups ($P=0.001$). Finally, there was a significant Block × age × learning conditions interaction $F (3, 88) = 2.98$, $P = 0.035$, with post hoc comparisons indicating that in consolidation phase, the percentage of correct answers of adolescents was more than all groups, also,10-year-olds children accuracy was similar to accuracy of adolescents. In addition, 10-year-olds were more accurate than 6-year-olds in response to sequential stimuli ($P < 0.05$).

Discussions and Conclusion

This study examined the effect of age-related changes and explicit - implicit awareness on motor sequence learning. The task distinguishes between explicit and implicit aspects of motor learning respectively by being aware and not being aware of the sequence (Robertson, 2007). As the results showed, all age groups in the performance of serial reaction time task progressed in the two components of speed and accuracy. The time difference and the percentage of correct answers in eighth and second blocks was significant in all groups, indicating improvement of speed and accuracy in all groups while performing the SRT. This means that practice and repeatedly response to serial stimuli resulted in, the speed of reaction to stimuli and response accuracy (percentage of correct answers) improved in both repetitive and random sequences. However, reaction time and response error in random sequences was more than a regular sequence, indicating that implicit learners responded to stimuli without the knowledge conscious about the order of sequences. This finding is consistent with the findings of Sekiya et al (2004), and Savion-Lemieux et al (2010) and shows the role of practice in improving the performance and learning.

The findings showed that there was a significant difference between the age of 6-years (explicit - implicit), 8 -years (explicit - implicit) 10 -years (explicit - implicit), and 18-15 years (implicit and explicit) for response time and response accuracy in the acquisition and consolidation phase. Overall, consistent with Savion-Lemieux et al (2010), our results showed a developmental progression in motor sequence learning within and across days of practice. For response time, groups of 6, 8 and 10- year olds children, in both explicit and implicit condition and in all blocks of task, had poorer performance than 18-15 year olds. Also in consolidating phase, there was no significant difference between the groups of 10 years and adolescents, but there was a significant differences in groups of 6 and 8- year olds, indicating that by the end of Day 2 (consolidation phase), 10-year-olds reached adolescents levels of performance, whereas 6- and 8-year-olds did not. For response accuracy, the greatest differences was in performance of the 6-year-olds and 8-year-olds groups. Errors of 6 years group (explicit - implicit) was higher than other groups. Also, the 8-year-olds were less careful than adolescents and 10 year-olds, but in Block 8, there was no significant difference between the adolescents and 10-year-olds. This indicates that probably, the accuracy of these groups was similar. Also in consolidating phase, No statistically significant difference was found between the groups of 8- year olds - 10 year olds in explicit conditions, and between groups of 8- year olds - 10 year olds and 10 year olds - adolescents in explicit and implicit conditions, Which indicates that in this stage, the precision of 8-year-olds children was similar to 10- year-olds and 10-year-olds reached adolescents levels of performance. These results show with the progress of the test, age-related differences in response time and accuracy of participants was observed.

In the present study, the developmental differences found for the two components of sequence learning (time and accuracy) are consistent with age-related changes in motor ability and the extended maturational timeline of motor pathways in the brain. Findings from recent structural neuroimaging studies show that global gray matter volume increases up until the age of approximately 6-10 and then decreases thereafter (Gogtay et al. 2004; Sowell et al. 2004; Wilke et al. 2007). This decrease in gray matter is mirrored by and is partially the result of concurrent global increases in white matter (Savion-Lemieux et al, 2010). It has been hypothesized that these increases may underlie decreases in nerve conduction time that are observed with development, and might be related to behavioral phenomena such as decreasing reaction times and increasing motor control associated with the improvement of fine motor skills across early childhood (Garvey et al. 2003).

Regardless of changes in cortical motor pathways, structural imaging studies have also shown changes in the white-matter pathways of the striatum and in the total volume of the cerebellum that continue into late adolescence (Sowell et al. 1999; Barnea-Goraly et al. 2005; Mackie et al. 2007). Taken together, the dissociation observed between our two behavioral measures of sequence learning is consistent with the hypothesis that accuracy or finger-stimulus association may rely predominantly on cortical maturation that occurs between ages 6 and 10; whereas motor timing and sensorimotor integration may rely on the maturation of white matter pathways that continue to develop into young adulthood.

Finding of this study showed that there was no significant difference between the two types of implicit and explicit learning (learning conditions) during the acquisition phase in response time variable, but there was a significant difference in response accuracy of motor sequence. Also, there was no significant difference between the two types of implicit and explicit learning in the consolidation of response time variable, but there was a significant difference in the consolidation of accuracy variable. These results indicating a difference in encoding and processing is these aspects, and the most important finding of this study is that the various components of movement (accuracy and speed) are performed and consolidated in different ways. Consistent with these findings, previous studies have proposed that different parameters of a motor sequence are likely to be acquired in separate but interacting systems (Hikosaka et al. 1999, 2002; Savion-Lemieux and Penhune 2010).

The results showed that there was significant differences between the participants of different age groups in two blocks at the end of the first day (the acquisition phase) with two blocks early on the second day, in two components of response time and accuracy. This represents confirms the phenomenon of motor memory consolidation in explicit and implicit different groups. Hemminger and Shadmehr (2008) stated that Increasing the length of offline time (resting phase), will increase improvement in memory skills. The researchers note that the best consolidation take occur during the off phase, 24 hours, which is also confirmed in this study, while our results are not consistent with Fischer et al

(2007) that showed children (between 7- and 11-years-old) showed smaller off-line gains, and thus poorer consolidation in the implicit task. Probably the reason for this discrepancy in results may be used types of tasks and tools, time and training efforts, and be research methodology. Our results are consistent with the Walker's model (Walker, 2005), to which the performance of a motor task will improve after a period of rest.

Overall, results of this study showed an age-related improvements in motor sequence learning. According to the findings of current study and the lack of significant learning effect for response time component but significant effect for the accuracy, applied conclusion that can be presented is that when education and rehabilitation interventions to children and adolescents, we can make use the benefits of implicit learning, because children can learn skills implicitly. Also, due to the presence of the consolidation of the participating groups, training sessions and rehabilitation interventions need to be determined in several sessions.

Notes on contributors

Sayed Kavos Salehi - PhD in Motor Behavior, Department of Physical Education and Sport Sciences, University of Tehran, Tehran, Iran

Mahmood Sheikh - Associate Professor, Department of Motor Behavior, School of Physical Education and Sport Sciences, University of Tehran, Tehran, Iran

Rasoul Hemayattalab - Associate Professor, Department of Motor Behavior, School of Physical Education and Sport Sciences, University of Tehran, Tehran, Iran

Davod Humaneyan - Assistant Professor, Department of Motor Behavior, School of Physical Education and Sport Sciences, University of Tehran, Tehran, Iran

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