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ASSESSMENT THE CAPACITY OF WORKING MEMORY BY COMPLEX MOTOR TASK IN 10-14 YEARS OLD CHILDREN

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ABSTRACT. The aim of the present study is to examine motor learning by capacity of working memory, focusing on kinesthetic, visuospatial sketchpad in nonclinical sample of school-aged children with complex motor task. Several researches are examining the capacity of working memory but there is very little study with nonclinical sample using complex motor task in test. The information obtained was intended to provide normative data before studying clinical populations. It can be declared that by quality the retrieval from the LTM is more auspicious than the retrieval form working memory even if the items are in the process of transcription/encoding. The information gathered in working memory did not find enough connections with movement patterns that were previously stored in the LTM, so the retrieval of them was slower and more imprecise. We can state that at the retrieval/reproduction of a maximum 30 seconds long complex set of movements the last items are still in working memory. In case of complex sport movements (as our exercises also were), the recall of the beginning of a set of movements the 30 seconds seemed short time for accessing/ encoding the data to LTM.

Keywords: *memory, working memory, capacity of working memory, school age, complex motor task*

Introduction

According to psychological knowledge memory can be divided into three phases (Atkinson et al. 2005, Eysenck & Keane, 1997): encoding (set data's in memory), storage (retain data's in memory) and retrieval (recovery data's from memory).

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Differentiation of memory system based on phases was published by Atkinson and Shiffrin (1968) at first. But this theory is really based on Ebbinghaus' theory from 1885. According to this the division of memory:

- short term memory (STM): approximately 15-30 sec, primarily acoustic origin, mainly verbal information. Main parameter is the 7+2 chunk role (Miller, 1956). It means that people can 5-9 items to note. To forget from the short term memory can be two reasons. First is the extruding when the latest information extrudes the oldest from this storage. Second is the eclipse when the repeat is not enough to recall.
- long term memory (LTM): the time limit of this storage is not well define. This phase is based on the short term memory – in point of fact the learned memory. In long term memory information encoding on their mean. Add contents the recording is get better. However the stored information are not ready, should recall them. Error of long term memory when recall is unsuccessful.

However latest and most common theories are accepting the division of memory according this (Baddeley, 2001):

- explicit memory: it means that visualization and recognition, conscious recall of affairs happened in the past the main function of this type of memory (episodic, semantic) – "know what".
- implicit memory: this type of memory can be catch out in advance particular perception, motor and cognitive assignment, without recall conscious information and experience that can cause improvement in achievement – "know how".

Types:

- skill (cycling, to bind lace)
- effect of pre-stress (accessibility of information is the result of previous stimulus)
- conditioning (salivation for word "lime")
- non-associative symptoms (habituation - cannot hear the tick of the clock)

Also the innovation of researches in the area of memory was to apply working memory instead of short term memory (Baddeley & Hitch, 1974). The main question of researches in the area of short term memory that what is the function of different working memory systems in the process of recognition and how does it works (Németh, 2002). It was an important measure that not a single-component, uniform capacity working memory but systems are mentioned. Further connected question these systems' study, which can offer useful help when examining the recognition background of working memory. Namely the capacity of working memory notably dependent on age (Németh, 2002).

Innovation of Baddeley's working memory model (Baddeley & Hitch, 1974) was that the short term memory is a multiple-component, active and dynamic system in which not only stores the information but operate with them. Working memory is postulated to be composed of a central executive control system monitoring two independent subsystems, visuospatial sketchpad for spatial processing and phonological loop for non-spatial, mainly verbal information processing (Baddeley, 1992). The visuospatial sketchpad liable for the visual and dimensional information storage and the phonological loop liable for verbal information storage. These components are well separated by behavioral and neurobiological methods. In the original model the function of central executive is to harmonize the two peripheries and make connection with long term memory. Among others the central executive is regulate the incoming information to aim of act. Simultaneously work of these subsystems means the working memory (Németh, 2002).

In alternative theories complex working memory are imagined various ways (Gathercole, 1999):

1. a flexible, uniform resource system, which liable simultaneously for storage and manipulating information (Daneman & Carpenter, 1980, Just & Carpenter, 1992);

2. an active part of long term memory which ruled by an inhibition mechanism system (Engle, 1999);

3. a call-stimulus base short memory system, which can access long term memory system structured by special development (Ericsson & Kintsch, 1995).

Development of subsystems of working memory is remarkably different. While the peripheral systems, like the grows of phonological loop's capacity ended sooner, that time systems measured by complex working memory exercises (n-back, reading content) development slower and subtended, representing worse achievement in elder age (Carpenter et al., 1994; Gathercole, 1999). Complexity of working memory and both of the central executive solely and development of it is very hard to define.

There are numerous measurement proceedings to map the verbal working memory like non-word repeating test, number volume, and reading content (Németh 2002). However very few or there are not studies in the visual-dimensional sketchpad and complex motor tasks connection.

The functioning of working memory via the central executive system is suggested to be strongly dependent on the frontal lobes (Baddeley 1996). Studies on nonhuman and human subjects (Fuster, 1989; Funahashi & Kubota 1994; Rypma & D'Esposito, 1999; Martinkauppi et al., 2000) also indicate the importance of the prefrontal cortex in working memory processing.

An age-related improvement has been reported in the performance of a variety of frontal lobe-dependent tasks including working memory, susceptibility to interference, and inhibition of inappropriate responses (Hale et al., 1997; Luciana & Nelson 1998; Luna et al. 2001; Bunge et al., 2002). Working memory in children has also been assessed recently by functional magnetic resonance imaging (fMRI) by use of verbal (Casey et al., 1995) and visuospatial (Thomas et al,. 1999; Nelson et al., 2000; Steenari et al., 2001) stimuli. These studies indicate that working memory-related activation in the child brain is of greater magnitude and distributed in a more diffuse manner compared with adult brain, possibly reflecting ongoing maturation and synaptic fine tuning in the child brain (Bourgeois et al., 1994; Casey et al., 2000). Previous research in children has assessed mainly verbal and visuospatial working memory (Casey et al., 1995; Fernández et al., 1998; Luciana & Nelson, 1998; Thomas et al., 1999; Nelson et al., 2000).

Vuontela et al. (2003) examined the effects of age and gender on audio spatial and visuospatial working memory in a nonclinical sample of school-aged children using n-back tasks. They stated that increase in age was related to better accuracy and faster performance in the memory tasks. Boys had shorter reaction times, were less accurate, and made more errors of commission (multiple responses) than girls. These differences between the genders were most evident in the youngest age group (6-8-year olds) and negligible in the oldest age group (11-13-year olds). Visual tasks were performed faster and more accurately than the corresponding auditory ones.

The other interesting side of the working memory researches is the aspects of primacy-recency. Behavioral and neurobiological evidence shows that primacy and recency are subserved by memory systems for intermediate- and short-term memory, respectively. A widely accepted explanation of recency is that in short-term memory, new learning overwrites old learning. Primacy is not as well understood, but many hypotheses contend that initial items are better encoded into long-term memory because they have had more opportunity to be rehearsed (Green, Prepscius & Levy, 2000).

Following a single exposure to learning, recall is better for items at the beginning (primacy) and end (recency) of a list than for middle items. This familiar u-shaped serial position curve is taken as evidence for two distinct memory systems (Glanzer & Cunitz, 1966). By one account (Waugh & Norman, 1965), primacy occurs in a system for long-term memory (LTM), which may maintain information indefinitely, and recency occurs in a system for short-term memory (STM), where unrehearsed information is generally lost in as little as 20 seconds. Accordingly, STM maintains the last few learned items, resulting in recency (Craik et al., 1970). Early list items, which have had the most opportunities for rehearsal in STM, have likewise had the greatest chance to be processed into LTM, resulting in primacy (Rundus, 1971).

Based upon our earlier study (Fügedi et al., 2006), the aim of present study to explore whether the part of working memory (visou spatial sketchpad) can reproduce the 7+2 items (Miller, 1956) without using phonological support but kinesthetic in a complex motor task? What shows the primacy - recency in an immediate serial recall in motor learning? What are the differences between ages and gender?

Material and Methods

Participants

A total of 40 children (mean age: 12.38; SD+ 1.213; gender 50-50%) participated in the study. The sampling was carried out with a likelihood random selection among the students of an elementary school from Hungary from 5th to 8th grade (10-10 pupils from each grade). Regular sport activity is taken by 90 % of them. The residual parts of the participants do nothing. Prior to testing, informed written consent was obtained from the parents of the children. It was explained to each child that the experiment could be discontinued at any time. The Ethics Committee of the School approved the study. The procedure was in accordance of ethical standards of human experimentation and with the Helsinki Declaration, revised in 1983. The children were not screened for psychiatric symptoms.

Stimuli

A general conditioning exercise series was selected due to participants' age, psychological, cognitive and motor maturity. The continuous movement set contains certain 10 elements like certain body position, leaning, circling, and direction changes and static body positions which can be performed by this age group, and which also fulfills the requirements of the National Curriculum. The elements signified the items. The movement set was chosen because it connects elements in the implicit memory storage system, therefore did not cause interference at all. Thus children could focus on reproducing. The presentation was no longer than 30 sec.

Procedure

Before the examination the aim of the asses was introduced to the children. It was demonstrated clear that after the stimulus they have to make the retrieval immediately. The movement sequence was presented by one of the author of this article and children had to do along with him. Only visual guidance without verbal instructions was used to exclude the phonological loop but assess the effect of kinesthetic. After the presentation the pupils had to reproduce the sequence in immediate serial recall. The movement sequence demonstrated by the students was recorded by a video camera, installed 5 meters away from the performance. Children took a sit back to the presentation to exclude the visual learning.

Data analyses

Three sets of analyses were performed. The first analysis included the 10 items to characterize the sample errors and to account for the general errors of the participants. Both descriptive and analysis of variance (ANOVA) were performed to explore the achievement and effect of capacity of working memory. The significance level was set at the alpha level $p < 0.05$. If the ANOVA gave a significant main effect, post hoc analyses were performed with Tukey HSD test. The effect of age was analyzed by treating it as a continuous variable and within four subgroups, too (10-11, 12, 13 and 14 year olds).

In the second analysis also the descriptive and analysis of variance (ANOVA) with Tukey HSD post hoc test were used to determine the cut point of continuity of retrieval and asses primacy and recency effect on working memory in the 10-item sequence.

In the third analysis we used descriptive and non-parametric Kruskal-Wallis test using scale data's (5 point) evaluating the items to discover the effect of gender, age and grade on quality of working memory and to explore the primacy-recency effect.

Quantitative and qualitative data were processed with the use of SPSS 18.0 for Windows software.

Results

Examining the capacity of working memory results show that from a 10-item complex motor task sequence children could retrieve the 7 + 2 items (Table 1, Figure 1).

Table 1. Successful items

Item	Frequency	Percent
5	9	22,5
6	12	30,0
7	4	10,0
8	6	15,0
9	8	20,0
10	1	2,5
Total sample(n)	40	100,0

In Table 1 can see that successful recall from working memory is 5 to 9 items (97,5%). Figure 1 shows the descriptive statistic of items (M: 6,88; SD +1,556) and we can state that capacity of working memory in serial recall is 7+2 with a bit rounding.

There were no differentiation in gender (F=1,258; df:1; p<0,269), grades (F=1,999; df:3; p<0,132), age (F=1,263; df:4; p<0,303), subgroups of age (F=1,152; df:3; p<0,341) in the achievement of working memory.

In second analysis the cut point of continuity of working memory and output of items were examined to explore the effect of primacy – recency (Table 2, Figure 2)

Table 2. Errors in continuity

Item	Frequency	Percent	Valid Percent
first item	8	20,0	20,5%
second item	4	10,0	10,3%
fourth item	1	2,5	2,6%
fifth item	22	55,0	56,4%
sixth item	2	5,0	5,1%
seventh item	2	5,0	5,1%
Subtotal	39	97,5	100,0%
Missing data	1	2,5	
Total	40	100,0	

Nevertheless the expectation the recall of 1st and 2nd item was not so successful (Table 1). In this case the error of items were 20,5% and 10,3%. The most failure item was the 5th item (56,4%) in the middle of sequence (Table 2, Figure 2). However the end of the sequence produced good results. The missing data means that one person could do the sequence without errors.

Assessing the gender (F=0,28; df:1; p<0,868), age (F=2,239; df:4; p<0,85), subgroups of age (F=2,636; df:3; p<0,65) there were no significant differences. At the same time a significant difference was detected in grades (Table 3) between the 6th and 8th grade. The 6th grade execute errors sooner (M=3,10; SD +2,025) than the 8th grade (M=5,33; SD +1,000).

Table 3. ANOVA of grades

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	27,000	3	9,000	2,890	,049
Within Groups	109,000	35	3,114		
Total	136,000	38			

Tukey HSD

(I) Grades	(J) Grades	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
5. grade	6. grade	,400	,789	,957	-1,73	2,53
	7. grade	-,700	,789	,812	-2,83	1,43
	8. grade	-1,833	,811	,127	-4,02	,35
6. grade	5. grade	-,400	,789	,957	-2,53	1,73
	7. grade	-1,100	,789	,512	-3,23	1,03
	8. grade	-2,233*	,811	,044	-4,42	-,05
7. grade	5. grade	,700	,789	,812	-1,43	2,83
	6. grade	1,100	,789	,512	-1,03	3,23
	8. grade	-1,133	,811	,509	-3,32	1,05
8. grade	5. grade	1,833	,811	,127	-,35	4,02
	6. grade	2,233*	,811	,044	,05	4,42
	7. grade	1,133	,811	,509	-1,05	3,32

* The mean difference is significant at the .05 level.

In the third analysis we used a 5-point scale to evaluate the items. 1 mean the worst, 5 mean the best rate. Table 4 shows the results of descriptive statistic of items. It can be seen that from the 1st item to the 8th item a relatively high performance characterized the achievement. However the last two items issue lower achievement.

Table 4. Statistic of achievement of items

Item	Mean	Std. Deviation	Variance
1	4,19	,738	,544
2	4,47	,609	,371
3	4,33	,676	,457
4	4,74	,505	,255
5	4,33	,816	,667
6	4,15	,675	,455
7	4,06	,639	,408
8	4,20	,645	,417
9	3,97	,981	,963
10	3,94	1,014	1,028

To explore the primacy – recency effect in working memory by quality, a non-parametric (Kruskal-Wallis) test was applied. Table 5 and 6 shows the differences in quality of the beginning and the end of sequence by gender. Boys achieve better than girls.

Table 5. Test statistics[a,b]

	First item	Ninth item	Tenth item
Chi-Square	3,976	10,322	12,792
df	1	1	1
Asymp. Sig.	,046	,001	,000

a Kruskal Wallis Test
b Grouping Variable: Gender

Table 6. Differences by gender

Item/girls	Mean	Std. Deviation	Variance
1	3,94	,680	,463
9	3,36	,929	,863
10	3,31	,873	,763
Item/boys			
1	4,44	,727	,529
9	4,53	,640	,410
10	4,56	,727	,529

There were no differences by grades neither of 4th to 8th but in age (Table 7, 8) and subgroups of age (Table 9, 10) in the 10th item. In the statistic both age and subgroups of age the 13 year group effect the lowest and 10-11 year group the highest achievement.

Table 7. Test Statistics[a,b]

	Tenth item
Chi-Square	11,554
df	4
Asymp. Sig.	,021

a Kruskal Wallis Test
b Grouping Variable: Age

Table 8. Differences by ages

Tenth item	Mean	Std. Deviation	Variance
10 year (1 sample)	5,00	.	.
11 year	4,50	,527	,278
12 year	3,73	1,009	1,018
13 year	2,80	,447	,200
14 year	4,20	1,304	1,700

Table 9. Test Statistics[a,b]

	Tenth item
Chi-Square	11,241
df	3
Asymp. Sig.	,010

a Kruskal Wallis Test
b Grouping Variable: Subgroups of age

Table 10. Differences by subgroups of age

Tenth item	Mean	Std. Deviation	Variance
10-11 year	4,55	,522	,273
12 year	3,73	1,009	1,018
13 year	2,80	,447	,200
14 year	4,20	1,304	1,700

Discussion and conclusions

Our results are similar to the theory of Miller (1956) concerning the capacity of working memory. It seems that the 7 + 2 unit capacity of working memory is partially applies to learn complex sport movements. There were no significant differences between genders, grades and ages.

The 5th item was the most unsuccessful that could be stated from the continuity of the exercises, and although the effect of primacy was manifested, it was weaker than the effect of recency. There were no surpassing results of the reproduction of the items at the beginning of the exercises (1st and 2nd item), because they were not accessing to the LTM. This is an interesting result, because the presentation of the exercises was not longer than 30 sec, and after that, we asked for immediate retrieval repetition without any practice. Two different explanation were formed on the grounds of the above mentioned.

One of the explanations is that in the case of retrieval motor exercises the 15-30 second storage time that applies to working memory is not enough for encoding. Encoding motoric visual pictures is a complicated procedure; working memory has to “try several times” to organize it to an easily retrievable pattern for the LTM.

The other explanation is that storing movements with different levels of difficulty have different storage time in working memory. According to that, in case of complex sport movements (as our exercises also were), the recall of the beginning of a set of movements the 30 seconds seemed short time for accessing/encoding the data to LTM. Further attempts are needed for examining the time of temporary storage and transcription of the first couple items of different movements from working memory.

The reproduction of the last couple items (9th and 10th) at the end of the exercises affirms the recency effect, so the retrieval from working memory was successful as it was also confirmed by our results. On the grounds of the above, we recon that at the retrieval/reproduction of a maximum 30 seconds long complex set of movements the last items are still in working memory. There were no difference between the genders at the examination of primacy and recency effect in the continuity of the movements, but there are statistically demonstrable differences between the ages, as between grades (6th and 8th grades). The 6th grade commits errors sooner at the retrieval of the exercise comparing to other grades. Younger students have already made errors at first couple items during the retrieval of the movements. This has supposedly two reasons, one is that they are inexperienced in learning set of movements, and the other is that their frontal lobe is still developing in this age, so this means that the maturity of regulatory mechanism influences the capability of learning sport movements.

In the course of quality evaluation of the items of the movements we can draw the following inference: retrieval from working memory reflects weaker result, than retrieval from LTM or retrieval of elements in the phase of transcription. It is noticeable that the last two items (9th and 10th) of the set of movements are still in working memory fall far behind the other items quality-wise. Presumably, the adaptation of the new stimuli engage the processor function of the central nervous system and this procedure – forming new movement models or altering/overwriting similar old movement pictures – is time demanding. It is important to note that during the quality evaluation of the primacy and recency effects the boys did better (Table 5 and Table 6). They not only were significantly more successful at performing the beginning of the movements, but also at the last items (9th and 10th) regarding the quality. We think that the reason of the difference between the efficiency is the more favorable movement learning background of the boys (they were more motivated and had more versatile experiences in sports than girls).

There were no differences at the quality evaluation between the grades, but there were statistically significant differences between ages and age groups in the case of the execution of the 10th item. The execution of the exercises within the13-year old group were the most unsuccessful, followed by the 12- and 14-year old, and quite striking that the efficiency of the 10-11-year old group was the most successful. On the grounds of the above, it can be stated that younger age groups show better quality results at the retrieval of the end-of-the-list items from the working memory than the older age groups. The 13-year old age is a breaking point considering the reproduction of the last items of the exercises in case of the quality appraisal. This coincides with our previous result as the performance of the 6th grade (13 years old students) in continuity showed the weakest result. Efficiency differences between age groups interpreted as motivation reasons. Adolescence is the period of remarkable changes in all aspects, when physical and psychical procedures canalize and restructure. It is vital to develop a high level movement learning skill at this age in the point of posterior motoric achievement.

As the summary it can be stated that the transcription of the first items to the LTM is in process, but it needs more time for consolidation. It is easy to retrieve motoric information from working memory. At the quality evaluation the reproduction of the last items did not showed as successful results as the items at the beginning of the movements. It can be declared that by quality the retrieval from the LTM is more auspicious than the retrieval form working memory even if the items are in the process of transcription/encoding. Presumably there are connections between the newly learnt movements and the patterns of previously acquired similar movements. During the process of learning, small alterations took place so these movements became easily recallable. The information gathered in working memory did not find enough connections with movement patterns that were previously stored in the LTM, so the retrieval of them was slower and more imprecise.

Our further study aims that with forming blocks of motoric information we elaborate strategies to different sports that efficiently support the movement learning capacity of competitors.

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