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# INTERFERENCES IN VISUO-SPATIAL SKETCH PAD AND KINESTHETIC SPAN

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**Abstract.** Purpose of the study: In this experiment, I wanted to examine further the effects of interferences, which might occur when we have occupied visuo-spatial sketch pad and we try to build motor representation in kinesthetic span. It also deals with further examination of kinesthetic span. Methods: three groups of participants had to store information in their phonological loop, visuo-spatial sketch pad, and in kinesthetic span. They had all three subsystems occupied differently, which could have showed relations between working memory stores. While storing information in their visuo-spatial span (showed on monitor), they had to learn (memorize) sequences of completely new movement. Results: Data obtained in the experiment, did not show any differences between groups, either in numbers of digits remembered, numbers of sequences of the movement. Conclusion: The lack of any differences between groups may suggest that kinesthetic subsystem and visuo-spatial sketch pad have their own stores for visual representation, or they are stored differently in each subsystem.

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*Key words:* Working memory - Kinesthetic subsystem - Motor learning

## Introduction

Atkinson and Shiffrin' theory of memory published in 1968 [2] described two different types of memory: short-term memory (STM) and long-term memory (LTM). The very first idea of these memories appeared earlier: Broadbent [5] was one of the first to describe it. Atkinson and Shiffrin' model was completed with STSS – short-term sensory store. It is the most peripheral memory and it is thought to involve a process that serves to hold massive amounts of information for a brief period of time [2]. It accepts information without much recording and loses rather

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quickly. Characteristics of short-term memory (STM) was: duration between 1s to 60 s, type of coding – more abstract than STSS (short-term sensory store) and less abstract than LTM, capacity – 7±2 items. STM was thought to be storage for information delivered from LTM and STSS. According to their theory, the way for memorizing and keeping information was rehearsal [1]. Information in long-term memory (LTM) was coded very abstractively, capacity and storage duration are seemingly limitless [1].

The division of memory into STM and LTM was supported by many statements, from which three seemed to be the most important:

1. rehearsal information in STM build its representation in LTM;
2. in LTM and STM are different types of coding information;
3. there is a significant difference in storage duration between STM and LTM.

All of these statements based on good experimental data. Experiments conducted by Rundus [21] or Glenberg, Smith, Green [15] supported Atkinson and Shiffrin' theory very well.

However further research, e.g. Craik, Watkins [8], Craik, Lockhart [7], showed that rehearsal itself is not sufficient to keep information for longer period of time. The most impressive example for the lack of relations between rehearsal and remembering was the case of Prof. Sanford, described by Neisser [18]. Even though Prof. Sanford estimated that he read the prayer book approximately 5000 times in about 25 years, he was not able to recall much of it [1].

Craik and Lockhart advanced a hypothesis, that the most crucial for remembering is the depth of processing information [7]. Very soon, the concept of levels of processing information dominated research in the area of memory. Craik and Lockhart claimed that remembering is better when rehearsal leads to deeper information coding. If we only rehearsed information on the very superficial level, we would not memorize them better. The time of rehearsing does not influence the memory either. These findings were destructive for Atkinson and Shiffrin' theory.

These days, Atkinson and Shiffrin' theory is arousing interest only from the historical point of view. However, still many authors are its followers [1]. The influence of that theory is still very strong - a new concept by Shiffrin [14] has been proposed – just to cite an example.

The distinction between STM and LTM based also on type of coding. In this distinction were found gaps as well – Kintsch and Buschke [16] affirmed that either semantic or acoustic information may be fundamental for memory in long and short period of time.

Ability to recall information is worsen very quickly after finishing learning. Atkinson and Shiffrin' followers argued, that we better recall information received recently than previously, because it is stored in STM. It is caused by recency effect [2].

We are able to explain data concerning rehearsal, type of coding and retention effects without theory, in which there is STM between short-term sensory store and long-term memory. Nevertheless, rehearsing information may influence memory. In 1986, Baddeley [3] suggested rehearsal systems, which could explain effects of rehearsing information and its influence on memory. Within rehearsal systems, Baddeley distinguished phonological loop, visuo-spatial sketch pad and central executive to control both. Phonological loop consists of two systems: storage for verbal information and storage for sub-vocal information (ability to inner-talk). Visuo-spatial sketch pad is responsible for rehearsing visual and spatial information. Baddeley [3] thought, that people are able to rehearse information through creating images somehow similar to sensory experiences during vision. Central executive controls rehearsal systems, it may give information to either of them, recycle record, it may also translate information from one system to another [5]. Baddeley [3] thought, that the central system needed its own memory store. In this storage are kept information which are not at the time in LTM, or in rehearsal system, or in sensory store.

According to Baddeley proposals, we recognize phonological and visual-spatial systems and we hardly know how are stored motor information for longer time than 2 s (duration of short-term sensory store) and what would happen, if we interfere information already stored in STM by giving additional visuo-spatial information. Experiments in which visuo-spatial sketch pad was involved were conducted by Brooks [6] or Baddeley *et al.* [4]. However, none of them referred to engagement of effectors.

A specialized working memory store for kinesthetic material has been recently proposed by Dolman *et al.*[12]. They have hypothesized that 3 domains of working memory: visou-spatial, verbal and kinesthetic, are directly involved in mental imagery and that impairment in working memory should affect mental practice efficacy [17].

*Purpose of the study:* In this experiment, I wanted to examine further the effects of interferences, which might occur when we have occupied visuo-spatial sketch pad by some information and we try to build a motor representation (effectors information) in kinesthetic span.

## Materials and Methods

*Participants:* I divided participants into three groups (15 persons each). Each group consisted of 15 men. All of them were between 21-25 years old. Participants came from students of the Academy of Physical Education in Wroclaw. All of them were healthy and participated in the experiment voluntarily. Before starting experiment all participants were told about task, its parts, and its rules. They were not informed about the main aim of the experiment, which was explained after having completed all tests. Tests were made one by one, one person at the time. Participants could resign from completing tests at any time of the project

*Task and procedure:* All participants in three groups were asked to remember 6 digit number (presented for 2 s on the computer screen). Exposition time of digits was fixed in PowerPoint (Microsoft Office®). Digits were displayed on the second (last) slide in the presentation. First slide with greeting was displayed as long as subject said that he/she was ready to start.

Then, participants were asked to watch a movement consisting of 13-sequences (appendix 1). They had to memorise this movement watching a video-cassette (duration 12 s) on TV screen. Movement and its sequences was taken from Latinek's Motor Capability Test [23]. Person presenting movement on video-cassette was a student, female. She did not participated in further tests.

It involved all muscles of limbs and trunk. After the video show, participants were asked to reproduce the movement (movement time about 12 s). After this time, they had to recall the 6-digit number. Duration time of all elements: exposition of digits, watching video-cassette and reproducing the movement was maximum 35 s.

Three groups differed one from another in the phase of memorising the movement.

- First group simply watched the cassette and then reproduced the movement (group I)
- Subjects from the second group had to watch the video and simultaneously subjects from this group were asked to describe loudly the sequences they were watching. While reproducing the movement they described it again (group II).
- Third group while watching the video, listened to a fairy tale (the text of the tale – see appendix 2). Tale was read from the recorder simultaneously with video-cassette show. Participants recalled the story reproducing the movement (group III).

In group I, I assumed that remembering digits will engage visuo-spatial span, and movement sequences will occupy kinesthetic span. Group II will describe and re-describe the movement, which reinforce the kinesthetic feelings and might, somehow, use some of the phonological loop capacity. In group III, participants will use additionally (to group I) their phonological loop to repeat the fairy tale.

The number of sequences reproduced was estimated on observation. On the questionnaires, on which all sequences were listed, I marked all sequences which were reproduced correctly. If participant mixed up order of sequences, I counted it as zero. Only those sequences, which appeared at correct time and were reproduced correctly, were counted as “good” (one).

All participants did CORSI test. It was one of the tests from Vienna Test System. It gives information about capacity of visuo-spatial sketch pad recency memory (UBS) and visuo-spatial learning (SBS). Both tests were made using computer system (Pentium III). CORSI tests enabled me to use its results as a co-variable and to make sure, that the groups are not significantly different one from another.

Both tests, which examine the memory span, are mainly focusing on the short-term memory that is provided with a limited capacity only. The assessment of the memory span is an important factor. The short-term memory is provided with a verbal subsystem as well as a visual-spatial subsystem. These subsystems can be damaged separately form each other by brain traumata, which is a proof of their -almost complete -independency. The Block-Tapping-Test for the registration of the immediate block span (UBS) assesses the capacity of the visual-spatial subsystem within the short-term memory. The theoretical background is characterized by Baddeley's concept of the working memory. The Block-Tapping-Test for the registration of the supra-block span (SBS) goes beyond the assessment of the short-term memory: sequences are used that exceed the respondent's visual memory span and thus make necessary to acquire specific learn processes. They imply to learn a frequently repeated sequence that is embedded into a pool of sequences with equal length. The respondent does not know that a sequence is repeated in the items that are presented: implicit learning is being operationalized. The test registers the number of repetitions until the relevant sequence is imitated correctly.

*CORSI administration:* The screen shows 9 irregularly placed dice. A pointer moves from one die to another in a sequence that grows with each new item group. The respondent is required to reproduce the order the dice were selected. After answering 3 items (with three sequences each), one more die is presented in the next item. The test is cancelled in case the respondent answers three sub-sequent sequences incorrectly.

In order to assess the implicit visual spatial learning (supra-block span), first the test registers the im-mediate block span of the respondent. Then sequences with one more block (die) are presented. The test encompasses 24 sequences altogether. Three sequences constitute one item, and three items (or four, including incorrect answers) always belong to one item group with the same number of dice. The test ends automatically after the respondent has reproduced all 24 sequences. Testing time: approx. 10 min.

*Statistical analysis:* To analyse data I used Statistica software (version 5,0 by StatSoft Inc.)

I used nonparametric Kruskal-Wallis' test (non-parametric ANOVA), since not all data – the number of remembered digits, number of remembered sequences, UBS scores, SBS scores - had Gaussian distribution (normal distribution). For these data I obtained following results: digits remembered Kolmogorov-Smirnov (K-S) test d=0.42843, p<0.01, Shapiro-Wilk (S-W) test W=0.62977, p<0.000; for sequences remembered K-S test d=0.13960, p>0.2, S-W test W=0.93695, p<0.0232.

For UBS scores - the K-S test was d=0.22723, p<0.05, S-W test W=0.89290, p<0.0003.

SBS scores resulted in K-S test d=0.31589, p<0.01, and S-W test W=0.81681, p<0.000.

U Mann-Whitney' test was used to examine individual differences between groups.

CORSI results – UBS and SBS results – were taken into consideration as a co-variant.

Kruskal-Wallis' ANOVA was conducted to examine main and interaction effects on working memory, depending on the source of interference (I - simply watching, II - describing a video, III - listening and recalling the tale).

## Results

In Fig. 1 are presented results of UBS test for three groups. There was no difference between groups. Kruskal-Wallis ANOVA (K-W ANOVA): H=0.22757, p=0.8925.

In Fig. 1 are also presented SBS results. K-W ANOVA H=1.7254 and p=0.422. No significant differences between three groups were noticed.

I compared the results of remembered numbers (6 digit numbers), the number of sequences correctly remembered, CORSI results (to differ subjects and as a co-variable).

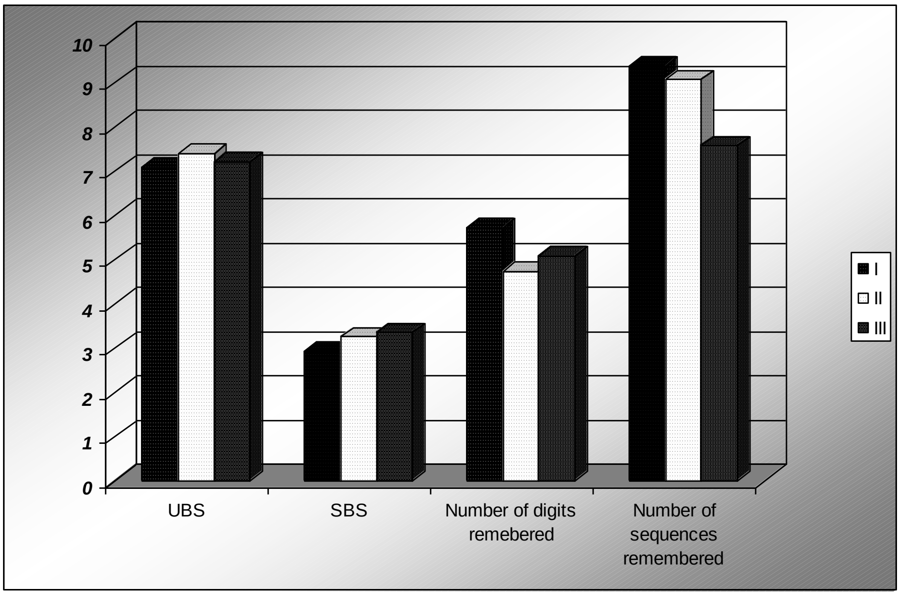


**Fig. 1**
Mean values of UBS, SBS, number of digits remembered and number of sequences remembered in all groups

**Table 1**
Sums of ranks, K-W values (H), and probability for each variable:
co-variables: UBS results, SBS, digits remembered,
dependent variables: number of digits and sequences remembered

| | UBS | SBS | Digits | Sequences |
|---|---|---|---|---|
| Group I | 326.5 | 267.5 | 403.5 | 393 |
| Group II | 357.5 | 330.5 | 285 | 354 |
| Group III | 351 | 348 | 346.5 | 288 |
| H | 0.2275 | 1.7254 | 4.2515 | 2.2168 |
| p | 0.89 | 0.42 | 0.11 | 0.33 |

K-W ANOVA showed no differences between groups, comparing their total number of sequences remembered. Neither comparison of digits remembered showed any differences between three groups. Test results and probability values are showed in Table 1.

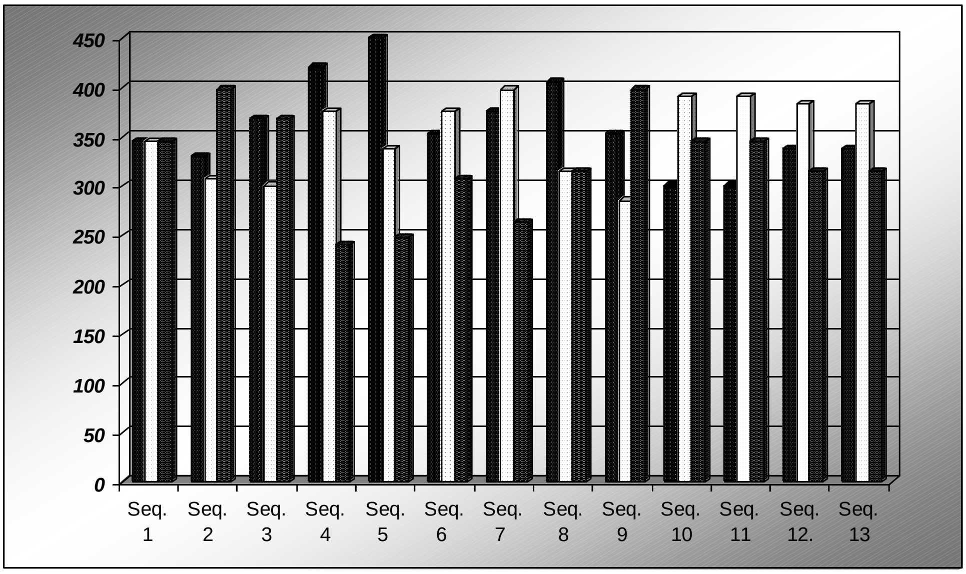


**Fig. 2**
Sum of ranks for individual digits

**Appendix 1.**
13 sequences of Latinek's test movement:
1. Standing position.
2. Simultaneously raising left arm aside and right arm in front; lowering both arms to standing position.
3. Simultaneously raising right arm aside and left arm in front; lowering both arms to standing position.
4. Bend knee, stay on right leg, left leg aside, arms down, touch the floor with fingers, back to standing position.
5. Bend knee, stay on left leg, right leg aside, arms down, touch the floor with fingers, back to standing position. Turn 90-degree aside.
6. Knee bend with hands on the floor.
7. Bend forward through straightening legs.
8. Knee bend with hands on the floor.
9. Back to standing position. Turn 90-degree aside.
10. Jump to astride position with arms straightened up (by raising them in frontal dimension).
11. Jump back to standing position.

12. Jump to astride position with arms straightened up (by raising them in frontal dimension).
13. Jump to standing position.

**Appendix 2**
Tale with rhyme verses in Polish. Translation is as follow:
Right in front, left to side,
Left in front, right to side,
Now we turn and jump up,
Knee bend down, legs flung, turn to side
Once again:
Knee bend down, legs flung, turn to side
Sit down, carry up, straight your legs,
Down again, up again,
Astride legs twice,
Jump as high as you can!

There were statistically significant differences in remembered individual digits. Results are showed on figure 2 and in Table 2.

**Table 2**
Kruskal-Wallis ANOVA results

| Sequence | H | p |
|---|---|---|
| 1 | 0 | 1 |
| 2 | 3.26 | 0.19 |
| 3 | 2 | 0.36 |
| 4 | 9.26 | 0.009 |
| 5 | 10.6 | 0.005 |
| 6 | 1.21 | 0.54 |
| 7 | 5.87 | 0.05 |
| 8 | 2.81 | 0.24 |
| 9 | 3.3 | 0.19 |
| 10 | 3.25 | 0.19 |
| 11 | 3.25 | 0.19 |
| 12 | 1.41 | 0.49 |
| 13 | 1.41 | 0.49 |

In first sequence we could notice very clearly the primacy effect – probability p=1, showed that all participants, regardless what and how they had their working memory busy, remembered this sequence. Some differences, were observed in sequence 4, 5 and 7.

In order to estimate, which groups differ from each other, I used U-Mann-Whitney' test. Differences in sequences 4 were noticed between groups I and III (U=52.5, p=0.01) and II and III (U=67.5, p=0.06). In sequence 5 differences were observed between group I and II (U=67.5, p=0.06), and between groups I and III (U=45, p=0.05).

In sequence 7, statistically significant difference was noticed between group III and II (U=67.5, p=0.06).

## Discussion

I found no differences between three groups. It may be due to the fact, that participants used different working memory subsystems to store information and to learn new tasks (SBS tests). Dolman *et al.* [12] proposed third subsystem, which would be responsible for storing kinesthetic materials. Pascal-Leone *et al.* [19] pointed, that working memory is involved in learning new motor skills, especially in the initial phases. During motor imagery – as it was in all three groups during watching video with movement sequences – the involvement of working memory, is also consistent with the brain activation patterns observed in several functional imaging of motor imagery [10,11,20].

I tried to make busy all subsystems, e.g. with listening to a tale, participants filled their phonological loop. Similar processes occurred, when participants had to describe the cassette and repeat it while reproducing movement. Participants' visual-spatial span was busy with digits remembered. This may suggest that in working memory can be created rich and diversified representation provided by combining verbal, kinesthetic, and visuo-spatial rehearsal. And they can be built in separate subsystems. Some explanation, of the fact that no difference was noticed, could give us research conducted by Dault *et al.* [9]. However, they did not distinguished kinesthetic subsystem, but they noticed that the addition of a working memory task, regardless of task type or task difficulty, forces the central nervous system to choose a co-contraction control strategy [9,13]. Co-contraction strategy also requires memory span. And, in my opinion, it may be the kinesthetic span, which is used mostly for such a strategy.

These results allow me to formulate a thesis, that kinesthetic span is a subsystem, not mentioned by Baddeley [3], however very important. It enabled participants to store information about a completely new movement they watched and then learned. At the same time, participants were able to store information in their visuo-spatial sketch pad (digits) and phonological loop (tale in III group or loud talk in group II). Baddeley described his problems with watching the American football match while driving [1]. He made up an image of game, which interfered with his ability to drive a car. Imaginary process interfered with his visual perception, what may suggest that these elements are parts of the same systems. In my research, either visual representation or verbal information (repeated tale, describing movements) did not interfere with producing (learning) movements. What's more, for memorizing movement sequences, kinesthetic span also needs some visuo-spatial representation. No differences between groups may suggest that kinesthetic span has its own visuo-spatial system, necessary for helping storing kinesthetic information. Looking at number of digits and sequences remembered (Fig. 1), we should notice that all together the number of elements stored at one time in working memory (e.g. for group I: 9 seq. + 5 digits=14 elements, for group II=14, and group II=11) is much higher than it supposed to be, looking at capacity of working memory (7±2 items).

Differences between group III and group I and II in memorizing sequence 4 and between groups I and III and I and II, in sequences 5, as well as, difference between group II and III in sequence 7, might suggest that all subsystems (phonological loop, visual –spatial sketch pad, kinesthetic span) have all together limited capacity. And overloading them, as it took place in group II and, especially, in group III, may influence one of the subsystems – in this case kinesthetic subsystem.

## Conclusions

This research did not show any differences between groups, which had different working memory subsystems occupied. They remembered new movement and sequences similarly, which suggest, that they used another working memory subsystem, firstly called by Dolman [12] as kinesthetic. This subsystem stores information about movement itself, but probably, it stores also kind of visual and spatial information essential to reproduce movement. It may be independent from visuo-spatial sketch pad distinguished by Baddeley [3]. All three subsystems: phonological loop, visual –spatial sketch pad, kinesthetic span may have limited capacity as a one unit.

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