

University Eötvös Loránd
Faculty of Education and Psychology
Doctoral School of Psychology
Cognitive Psychology Program

Kárpáti Judit

Spatio-temporal processes in memory

Theses of Doctoral (PhD) Dissertation

Supervisors: Király Ildikó, PhD and Kónya Anikó, CSc.

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Introduction

Our studies are focusing on episodic *binding* processes in memory. According to Tulving's (1972) model, episodic memories are complex representations from our past. Although these complex units contain multiple components and attributes of events, as Tulving claims contextual (spatial and temporal) attributes have a prominent role in both encoding and retrieving specific memories. In our studies, we examined the basic episodic unit (*what, where and when*) in the context of short-term memory processes. In our view, this basic episodic binding mechanism may be the initial step to form complex long-term episodic memories. The main purpose of our studies was to differentiate between *automatic* and *effortful* components of episodic binding. Studies in adults have shown that the binding of object identity and object location (what and where) is automatic (Köhler, Moscovitch and Melo, 2001) however several researches have shown that a more complex binding involving also temporal order of objects (what, where and when) is an effortful process (Van Asselen et al, 2006; Dolugu et al, 2012). However, it should be highlighted that the above-mentioned studies treated together the *verbal serial* (serial order of concrete objects) and (sequential order of identical objects) information which we attempted to separate in our studies. The simple binding tasks measured memory span in spatial localization of images (*spatial task*, what and where), temporal order of verbal items (*verbal task*, what and when) and sequential organization of homogenous stimuli (*sequential task*, where and when). The *complex task* which is equal to the basic episodic unit (what, where and when) integrates verbal serial and spatial sequential information.

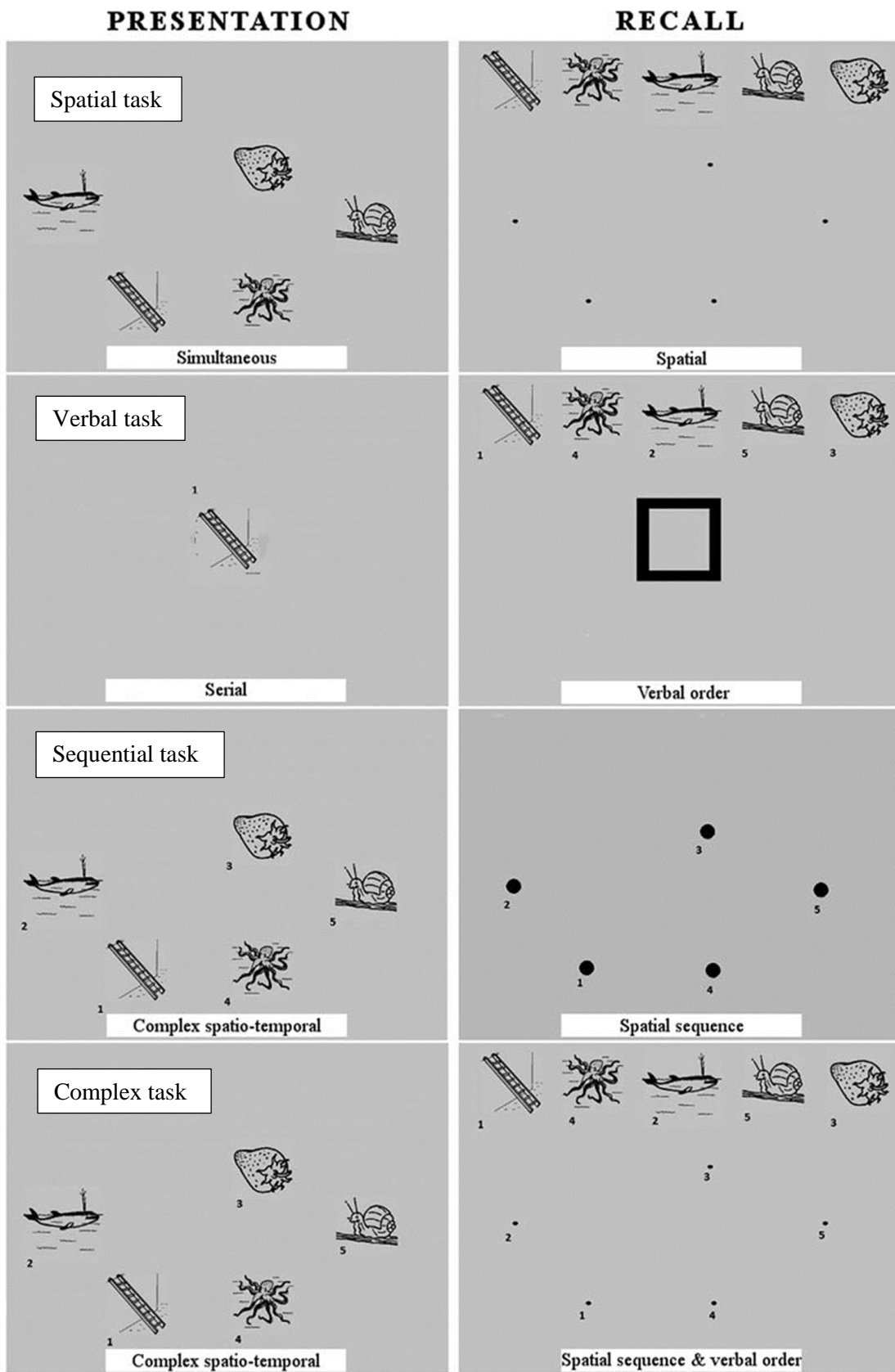


Figure 1. Presentation and recall phases of the memory binding tasks

Theses

The doctoral dissertation includes studies which are built upon each other:

1. In the initial study, our main focus was on the separation of automatic and effortful binding processes in short term memory. According to previous studies in the subject (Köhler, Moscovitch and Melo, 2001; Van Asselen et al, 2006; Dolugu et al, 2012) we expected less cognitive effort in simple binding tasks (what and where, what and when, where and when) than in complex episodic integration (what, where and when). The developmental approach gave us the opportunity to differentiate more precisely between basic and high level binding processes in memory.

2. Our second study's aim was to confirm the results of the first study's conclusions by the examination of a clinical group of children (benign childhood epilepsy). We assumed that complex memory integration processes are related to the frontal functions of the brain.

3. Finally, the convergent results of healthy and clinical groups directed our attention to the exploration of the role of attentional and executive functions in episodic binding processes. Previous studies (Picard et al, 2012; Rende, Ramsberger and Miyake, 2002; McCabe et al, 2010) and a preliminary investigation (Bakos and Kárpáti, 2012) implied the dominant role of attention and fluency functions in episodic binding. However, during our studies further executive functions (inhibitions and shifting) emerged as possible other important related mechanisms in memory integration processes.

1. Automatic and effortful components of episodic binding processes

Methods

The spatio-temporal binding tasks were created by Kónya Anikó and Boha Roland (Boha, 2012, *manuscript*). The computerized tasks measured *memory span* based on the original method of Postma and his colleagues (2006). 115 children (54 boys and 61 girls, M: 7,94; SD: 1,42) and 41 young adults (20 men and 21 women; M: 21,49; SD: 2,23) participated in the study.

Results

Our results show continuous development in all the four binding tasks. In childhood, there were more temporal errors than spatial errors in the complex spatio-temporal task, while in adulthood there were no differences between the temporal and spatial errors. In our view, this developmental difference may be explained by the cognitive effort in the integration processes of spatial sequential and verbal order of concrete objects. Based on the memory span differences, it appears that the *complex* spatio-temporal task was more difficult than simple spatio-temporal binding without object identity (sequential task) for both children and adults. These results support the notion that verbal serial information is represented distinctly from spatial sequential information and the integration between these memory components is an effortful process. In the further studies, our aim was to explore the exact nature of high level cognitive abilities related to episodic binding processes.

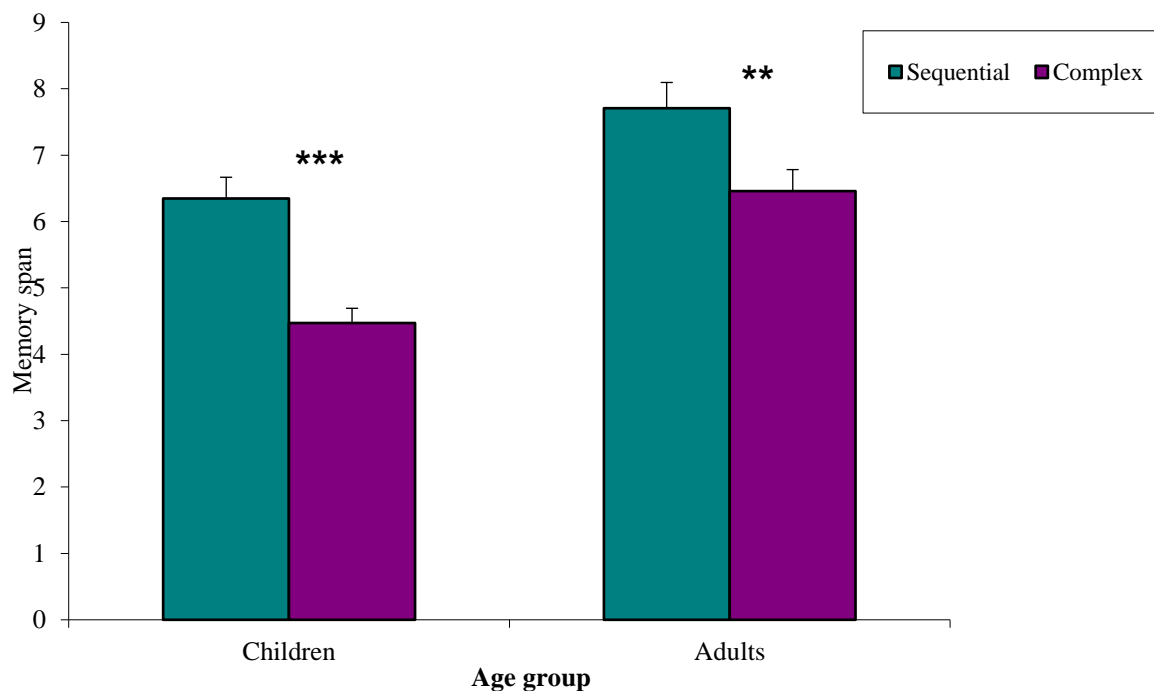


Figure 2. Memory span for sequential and complex task in childhood and adulthood (***= $p < 0,001$).

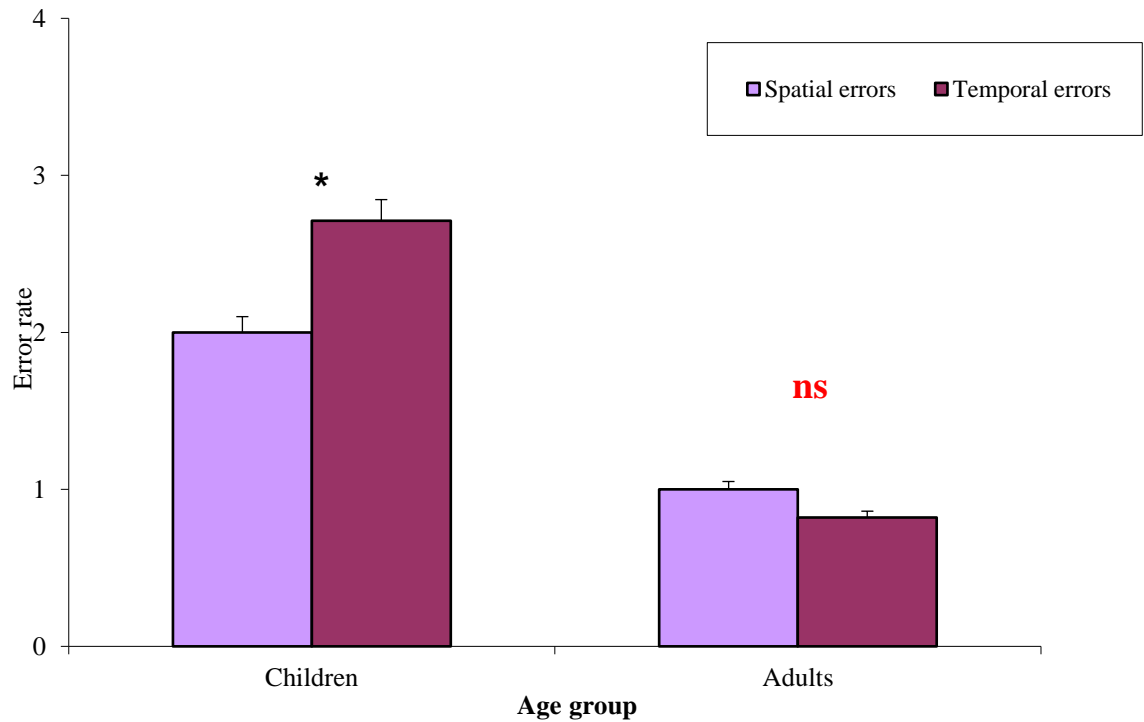


Figure 3. Spatial and temporal errors in childhood (6-10 years) and in young adulthood in complex task (*= $p < 0,05$).

2. Episodic binding processes in a clinical group (Benign epilepsy of childhood with centrotemporal spikes, BECTS)

Methods

We assessed the performance of children with BECTS in our spatio-temporal binding tasks. 17 children (6 girls and 11 boys) aged 6 to 13 years with BECTS (M: 9.02 years; SD: 2.49) and 17 healthy children (M: 9.22 years; SD: 2.48) matched as closely as possible for age, sex, and intelligence quotient.

Results

We found that children with BECTS have no deficits in simple spatial, verbal and sequential tasks, however they had lower scores than the controls in the complex spatio-temporal task (multiple integration of episodic components of what, where and when). Our findings imply no specific memory dysfunction in BECTS, but suggest difficulties in integrating information within working memory which presumably relating to the frontal lobe disturbances in BECTS (e.g. Praline et al, 2003; Kanemura et al. 2011). These results are consistent with our previous

findings and together they imply that episodic binding processes are linked to high level cognitive functions.

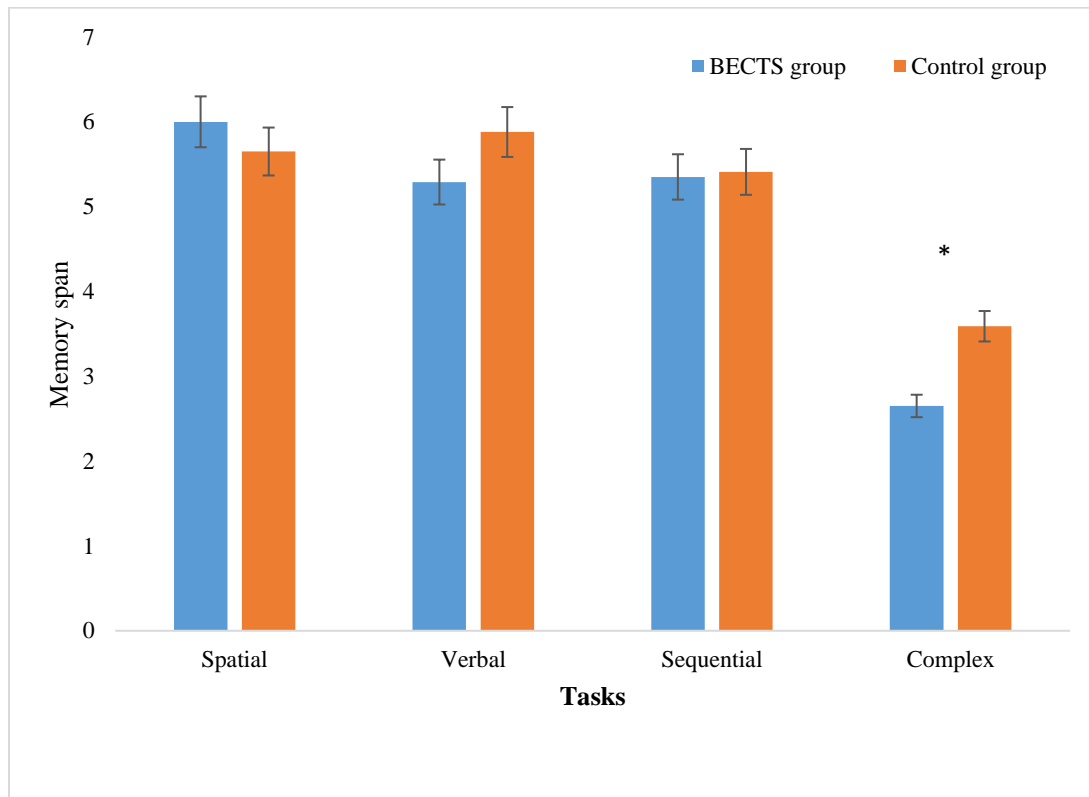


Figure 4. Memory span in the binding tasks in BECTS and control group (*= $p < 0,05$).

3. Control processes and episodic binding

Methods

The aim of our studies was to explore the specific control processes relating to spatio-temporal memory binding. Our study included one elementary school and two separate young adult groups.

- 55 children between the ages of 8 and 11 years (20 boys and 35 girls; M: 9,94; SD: 0,70)
- 42 young adults (29 women and 13 men; M: 22,74; SD: 2,49)
- 62 young adults (37 women and 25 men; M: 20,98; SD: 2,83)

As in our previous studies, participants performed the computerized spatio-temporal binding tasks. Furthermore, in childhood we assessed executive functions with *verbal* and *nonverbal fluency* tasks and attentional capacity with *Bells attention task*. Studies with adults were partly identical and partly different. In the first adult study we measured attention with *Attention Network Task (ANT)* and executive functions with verbal and nonverbal fluency task as in our developmental study. In the second adult study, for further examination of the role of executive functions, participants also performed *Stroop* and *Trail-making* tests.

Results

Our results show that complex episodic binding (what, where and when) require greater executive control than the simple modality-specific tasks in both childhood and in adulthood. More precisely, it seems that inhibition and shifting have prominent roles in episodic binding processes. Besides this, the results of children and adults are different in several aspects. In childhood general attentional functions may have a greater involvement in binding processes while in adults specific executive functions may be sufficient to support memory integration processes. On the other hand, concerning the sub-mechanisms of episodic binding, in children verbal organization demand greater executive involvement while in adults spatial localization seems to be the more effortful process. This difference may originate from the educational and environmental differences between the two age groups.

General discussion

In the above presented studies, our aim was to explore cognitive processes in connection with spatio-temporal binding abilities. Our studies with healthy children and young adults imply that complex integration of what, where and when demand conscious high level cognitive abilities while the distinct spatial and verbal and - especially - sequential elements of basic memory episode may depend on less effortful processes. Our clinical study with children with benign centrotemporal epilepsy highlighted the possible role of frontal functions in the episodic binding mechanisms. Based on these results, in our final studies, our aim was to define specific high level cognitive functions relating to spatio-temporal integration processes. In summary, it emerged that in childhood general attentional functions have a greater involvement in binding

processes while in adulthood specific executive functions have a dominant role in these memory operations. However, in both of the age groups inhibition and shifting seems to have a significant role in the short-term complex integration processes.

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