Memory for Object Location: A Span Study in Children

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Abstract

A number of studies suggest that object location memory might depend upon a variety of component processes, namely remembering which locations in space were occupied and remembering the identity of the objects that occupied each location. The aim of the present experiment was to analyse, using a span procedure, the development of spatial memory in three experimental conditions: positional reconstruction, object-location binding, and the integration of these two in the combined condition. A total of 160 children aged 6, 8 and 10 years were tested. The findings of the present study provide developmental spans in each relocation condition. Results also show an age dependent improvement in all conditions, showing that spatial location is not automatically encoded and different developmental patterns for each of the relocation conditions considered, suggesting that spatial memory does comprise a number of different component processes.

Introduction

Spatial memory enables us to find our way in our environment but also to find objects such as keys or glasses that we have recently used and deposited somewhere in our surroundings. Regarding this ability it has been suggested that it might depend upon a variety of component processes, specifically memory for the locations of individual items and memory for occupied locations, that may be affected differently by variations in stimulus characteristics or task demands (Puglisi, Park, Smith and Hill, 1985). More recent studies (Postma & De Hann, 1996; Schumann-Hengsteler, 1992, Shoqierat & Mayes, 1991) also suggest that two separate spatial processes may be involved in short-term object location memory. First, one needs to remember the precise position occupied in a given space (positional encoding per se), then one has to decide which object was at which position (object-to-position assignment). Evidence from studies in adults shows that disrupting the phonological loop, with a concurrent verbal task (articulatory suppression), interferes with the object-to- position assignment process, suggesting that it relies to some extent upon verbal coding (Postma & De Hann, 1996). On the other hand, interfering with the visuo-spatial sketchpad with a simultaneous activity, such as repeated tapping of a spatial pattern, disrupts positional encoding process (Pickering et al., 2001).

With regards to object-location assignment there is agreement in the literature that a developmental improvement in the number of associations remembered is found. Schumann-Hengsteler (1992) reported that children improved with age in remembering the locations of specific objects. In this study a picture reconstruction task with simultaneous presentation of scene-like visual spatial arrangements was used. Subjects had to recognize objects and reconstruct the initial spatial arrangement. In the first experiment an age dependent improvement in remembering the locations of specific objects was shown in 4 and 11 year olds. The second study with 3 and 7 year olds revealed similar results. In line with these findings Walker, Hitch, Doyle, and Porter (1994) reported a study in which a probed memory task was use to investigate children's short-term visual memory for an object's spatial location or colour. The results of their second experiment indicate that there was a developmental improvement in memory for spatial location in children of 5 and 7 years of age. Other studies have also found this developmental improvement for tasks in which different objects have to be linked to different locations (Siemens, Guttentag and McIntyre, 1989, Rossi-Arnaud Alfano, Longoni, 1999).

On the other hand, with regards to spatial location, Hasher and Zacks (1979) suggested that it is encoded and retained automatically and that as a consequence of being automatic, memory for spatial location should not show any developmental enhancement. Although a number of studies have investigated the development of spatial memory (Orsini, Grossi, Capitani, Laiacona, Papagno & Vallar, 1987; Logie & Pearson, 1997; Hamilton, Coates and Heffernan, 2003), few have specifically addressed the issue of the development of positional encoding per se. Schumann-Hengsteler (1992), in the experiments mentioned previously, observed that whereas children improved with age in remembering the locations of specific objects, there was no age effect on memory for the critical loci themselves. Other results are in contrast with the latter study and report a developmental improvement in positional encoding (Conte, Cornoldi, Pazzaglia & Sanavio, 1995; Siemens et al., 1989). Siemens et al. (1989) presented children aged 4 to 8 and college students with 3-7 items in different cells of a 4 * 4 matrix and required to remember either the identity, the locations, or both identity and locations. In both experiments there were much larger age differences in retention of location than of identity information. Recent work by Postma, Wijnalda and Kessels (2001) and by Rossi-Arnaud, Alfano, Longoni (1999) used Postma and De Haan's experimental paradigm and compared the performance of children in 3 different relocation conditions. In the first condition, named the position-only condition all objects are the same and hence only precise locations have to be remembered. In the object-to position condition the positions where objects should be replaced are marked hence only the association between object identity and location needs to be remembered whereas in the combined condition both locations and object-location associations have to be coded. Both studies suggest that there might be age differences in memory for positions per se, however both studies use a fixed length procedure, i.e. children are shown a fixed number of stimuli simultaneously, but none have really addressed the question of how many stimuli children can actually encode and remember at each age considered. The latter is better examined using a span procedure.

Spatial span has generally been determined using the Corsi's block test (e.g. Orsini et al.,; Isaacs and Vargha-Khadem, 1989, Logie and Pearson, 1997) which entails a sequential presentation of the items to be remembered, one of the aims of the present study was to determine the span in children of different age groups for visuo-spatial information presented simultaneously. Differently from studies which have measured span using the recall of occupied cells in a matrix (eg Wilson, Scott and Power, 1987; Miles, Morgan, Milne and Morris, 1996; Pickering, Gathercole and Hall, 1997) in the present study span will be measured in parallel for each of the relocation condition previously described, namely positional reconstruction, object location binding, and the integration of these two. Firstly, this allows to examine if performance in the three conditions show different developmental trends. This pattern of results would on the one hand lend some support to the idea that they are different memory processes and on the other hand would allow to understand whether some processes develop before others do, in particular whether nonassociative processes (e.g. positional reconstruction) develop before associative processes (object-to-position assignment). Second, results will answer the question of whether there is a developmental improvement for each of the three spatial memory processes described above, including positional encoding per se. In the Experiment described below, children aged 6, 8 and 10 years were thus randomly assigned to one of 3 groups and a span procedure was used in each of experimental conditions mentioned above (Position only, Object-to-position, Combined).

Method

Participants

A total of 160 children in a junior high school in middle class areas in Rome, Italy, participated in the study. There were 52 children aged 6 (mean age= 6 years 1 month), 54 children aged 8 (mean age= 8 years 4 months) and 54 children aged 10 (mean age= 10 years 3 month). In each group children were randomly assigned to one of 3 groups according to type of condition considered (Position, Object to position, Combined).

Materials

The stimuli used were 10x10 cm paper cards arranged in a 4x4 paper matrix on a table, with each cell measuring 10x10 cm. In the present experiment in the object to position and combined condition the stimuli were line drawings of familiar object, while in the position condition the stimuli were black paper cards.

Procedure

Each child was tested individually in a quiet testing room in the school, using a classical span procedure, as used in Gathercole et al. (1994). Cards were arranged over a paper matrix. On any given trial, the examiner displayed a particular sequence of cards. Sequences of increasing length, starting from length two, were presented if the subject correctly recalled two strings for each length. If the child failed to repeat both of the two lists at one length, no further lists were given. When the child correctly recalled only one of the first two lists at a particular length, a third list of the same length was given. If the third list was correctly repeated, trials at the next length were given. If the child incorrectly repeated the third list, testing stopped. Span was scored as the maximum length at which the child correctly recalled at least two lists. According to Postma e De Hann's paradigm, one relocation was the " Object-to-Position" condition, in which the position where object should be relocated were marked on the matrix; the other one is the " combined" condition in which subjects had to relocate the cards on the matrix, without any marking of the original positions. In the position condition children had to remember only the exact place occupied on the matrix by the black paper cards.

Data analysis

Three separate univariate analyses of variance (ANOVA) with one between- group factor, age group (6, 8 and 10 years of age), were performed on the total number of correctly relocated items in the three different tasks considered, position only, object-to position and combined. The Newman Keuls post hoc test was applied where necessary. Further, a trend analysis was also performed to identify if there was a significant linear trend.

Results

Table 1: shows the mean span and standard deviation for correctly relocated items in the three different age groups in the three different relocation conditions.

SPAN	Position		Object-to Position		Combined	
AGE	Mean	S.D.	Mean	S.D.	Mean	S.D.
6-year-olds	3,05	1,59	3,88	1.57	2,77	1.06
8-year-olds	4,66	1,23	5.10	1.04	2.51	1.42
10-year-olds	4,69	1,31	5,88	1,69	3,72	1.51

Position only. When the mean span for correctly remembered positions in children aged 6, 8 and 10 years was analysed, statistical analysis indicated a significant main effect of age $F(2,46)= 4.74$, ($p = .01$) $p.<.05$. Post hoc comparisons indicated that the span for correctly remembered positions is significantly lower in 6 year-olds than in older children ($p= .03$ when comparing 6- and 8-year-olds; $p= .01$ when comparing 6- and 10-year-olds). Children of 8 years of age did not differ from 10 year-olds in the span for positions remembered ($p = .45$). Finally, remembered positions showed a significant linear trend $F(1,46)= 6.72$, ($p=.01$) $p.<.05$.

Object-to-position. When the mean span for correctly relocated objects in children aged 6, 8 and 10 years was analysed, statistical analysis indicated a significant main effect of age $F(2,54)=8,07$; $p<.001$. Post hoc comparisons indicated that the span for correctly relocated objects is significantly lower in 6 year-olds than in older children ($p < .05$ when comparing 6- and 8-year-olds; $p < .001$ when comparing 6- and 10-year-olds). Children of 8 years of age did not differ from 10 year-olds in the span for objects relocated ($p=.12$). Lastly, correctly relocated objects showed a significant linear trend $F(1,54)= 15.86$, $p < .001$.

Combined When the mean span for correctly relocated objects in children aged 6, 8 and 10 years was analysed for the Combined task, statistical analysis indicated a significant main effect of age $F(2,54)=15.52$; $p<.001$. Post hoc comparisons indicated that the span for correctly relocated objects is significantly higher in 10 year-olds than in younger children ($p < .001$ when comparing 6- and 10-year-olds; $p < .001$ when comparing 8- and 10-year-olds). Children of 8 years of age did not differ from 6 year-olds in the span for objects relocated ($p = .17$). Lastly, correctly relocated objects showed a significant linear trend $F(1,54)= 29.04$; $p<.001$.

Discussion

In the present study developmental changes in three spatial processes, namely in the retention of spatial locations per se, in the assignment of objects to locations and in the integration of these two, were analysed. A first aim of the present study was to measure the span for spatial locations, the span for the association between objects and their locations and the span in a spatial memory task requiring the ability to combine these two processes. A second goal was to test the hypothesis that there is a developmental trend in these spatial processes and, finally, a third objective was to assess whether there are selective developmental patterns for these distinct components of location memory, specifically whether the two basic processes, such as remembering the locations per se or assigning objects to locations, develop earlier than the ability to combine them.

Regarding spatial span, whereas a number of studies have analysed spatial span in children either with a Corsi's block test (e.g. Orsini et al.,; Isaacs and Vargha-Khadem, 1989, Logie and Pearson, 1997) or with the recall of occupied cells in a matrix (eg Wilson, Scott and Power, 1987; Miles, Morgan, Milne and Morris, 1996; Pickering, Gathercole and Hall, 1997) none have to date analysed, in parallel, the development of span for the three spatial processes previously mentioned. The studies which have operated such a distinction between processes have used a fixed length procedure. The findings of the present study are important because they provide spans for children belonging to three age groups for the three spatial processes considered which have been tested in parallel in three different relocation conditions. These results can be useful for further studies in children or for a neuropsychological use of the paradigm presented.

With regards to the hypothesis that there is a developmental trend for all the processes considered, our results indicate that there is an age dependent improvement in all conditions. The clear age effect found in the object-to-position condition is in agreement with the literature which suggests an improvement with age in memory for object-location associations (Postma et al., 2001; Siemens et al., 1989; Schumann-Hengsteler, 1992). On the other hand, as previously mentioned, there are a number of contradictory results with regards to a developmental enhancement in memory for spatial location per se. The significant age effect found in the present study in the position only condition is in agreement with previous data showing that location memory is consistently affected by age (Puglisi et al., 1985; Siemens et al. 1989), with older children performing better than younger ones (Postma et al., 2001; Rossi-Arnaud et al., 1999). The latter findings argue against the view that occupied-location information is encoded automatically (Hasher and Zacks, 1979).

When looking at the developmental patterns it is interesting to note that children first improve their ability in remembering the spatial locations per se and in associating the objects to the locations. Our results show that there is a significant improvement both in positional reconstruction and in object-location binding at 8 years of age. It is only later that children improve in the ability to perform positional reconstruction and object-location binding together. Our data show a significant improvement in the combined condition at age 10. This pattern of results suggests that the combined condition is indeed the most complex relocation condition and that the ability in this distinct component of object-location memory depends upon the development and integration of the two other more elementary processes. This selective developmental patterns for the three distinct component of object-location memory is what was expected although, using the same experimental paradigm, Postma et al. (2001) had not found this pattern of results in children. However, in their study, as suggested by the authors, there was probably a practice effect which masked the higher complexity effect in that, in their procedure, the combined condition was always performed at the end of the experiment.

The developmental patterns observed for the three spatial abilities considered in the present study might be related to the way children encode the information in each condition. For instance, it has been reported that a concurrent verbal task strongly interferes with the object-to-position assignment task (Postma & De Haan, 1996) suggesting that this process depends on verbal encoding. In children, however, verbal encoding might not be effectively applied until the age of 8 years (Hitch, Halliday, Schaafstal & Schraagen, 1988). Further studies should thus analyse which strategies are used in each relocation condition by children of different ages.

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