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RESEARCH ARTICLE

Spatial Descriptions Eliminate the Serial Position Effect

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Abstract:

Aims:

The present study aims to investigate the occurrence of the serial position effect in the recall of items verbally presented in three different contexts.

Background:

The serial position effect has been studied with both verbal (*e.g.*, words) and visuospatial (*e.g.*, locations) stimuli but not with verbal-spatial stimuli (*i.e.*, spatial description of an environment). In particular, a spatial description of an environment has both spatial information and a meaningful context.

Objective:

The objective of the present study is to determine whether the use of different contexts (namely, a classic word list, a spatial description of a room, and a narrative without spatial information) can alter the serial position effect.

Methods:

Depending on the condition, participants were exposed to a) a list of objects, b) a spatial description of a room containing the same objects; c) a narrative presenting the same objects in lack of spatial information. After this learning phase, participants performed a recognition task.

Results:

The recognition task revealed different accuracy distributions in the three conditions. In particular, in the spatial description condition, the accuracy distribution did not change across the item position.

Conclusion:

This result is in line with previous studies with visuospatial stimuli. Thus, it seems that spatial descriptions are a particular kind of verbal stimuli, which are encoded similarly to visuospatial stimuli. Overall, these outcomes support the idea that spatial descriptions elicit a spatial representation, which enhances item retention and eliminates the serial position effect.

Keywords: Spatial description, Serial position, Context, Verbal stimuli, Visuospatial stimuli, Serial position effect.

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1. INTRODUCTION

1.1. Spatial Descriptions Eliminate The Serial Position Effect

Memory for serial order is essential for the management of high-level cognitive activities [1], influencing the ability to recall information independently of the position of the items.

Cognitive studies have extensively explored the problem of serial order in different domains, employing different methodological procedures, and they repeatedly reported evidence consistent with the serial position effect. The serial position effect reflects the systematic changes in accuracy across an item's position, showing a significantly higher performance when responding to the first – primacy effect – and to the last items – recency effect – of a sequence [2], whereas the middle items tend to be forgotten. The presence of the serial position effect is typically displayed by a U–shape

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curve when plotting the recall accuracy as a function of the serial order of the items [1].

An extensive amount of evidence has demonstrated the occurrence of the serial position effect in different situations involving the employment of verbal materials, such as letters and words [3 - 5]. According to Hurlstone *et al.* [1], the main use of verbal material in research dealing with the serial position effect may be due to the easy wayof handling, that is, building, manipulating and testing verbal material compared to non–verbal material. On the other hand, it is possible that memory functions are sensitive to the stimulus domain [6], showing different results in the non–verbal domain. As for non–verbal material, there are controversial results in studies using visuospatial stimuli.

Comparing verbal and visuospatial material has not provided well-established and consistent results. Indeed, Cortis *et al.* [7] found the same effect of serial order for both verbal and visuospatial material, claiming that different results across modalities found in previous studies could depend on the not–uniform methods used [8 - 10]. Thus, their findings seem in line with the assumption of Guérard and Tremblay [11], who proposed a functional equivalence of serial recall, suggesting that the serial order may be elaborated in similar ways across the domains [1]. However, despite providing encouraging results, some critical points in previous studies should be considered. In a study by Cortis *et al.* [7], the overall accuracy differed between verbal and visuospatial stimuli, and primacy and recency effects were weaker for visuospatial than for verbal stimuli. Moreover, Hurlstone *et al.* [1] highlighted that the serial position effect is well–established in the verbal domain. At the same time, further investigation is necessary for the visuospatial domain due to not totally clear results. Thus, it seems that the serial position effect is more pronounced in the verbal domain compared to the visuospatial domain [12].

It is interesting to note that in the visuospatial domain, different types of material were used to test the serial order influence, such as sequences of visuospatial locations [9, 13, 14], visuospatial movements [15, 16], and routes navigation [17, 18]. A multitude of different stimuli employed, but to the best of our knowledge; no study has investigated whether a verbal–spatial type of stimuli would determine the same pattern of results. In particular, there is no evidence clarifying whether the memory recall of items in a spatial description (*i.e*., verbal description of an environment) is affected by the serial order differently from the recall of items in a classic word list.

Previous evidence in spatial literature suggests that an environment verbally described is spatially, and not textually, encoded and fosters the development of a mental representation with the spatial characteristics described [19 - 21]. Moreover, spatial descriptions seem to be functionally equivalent to directly perceived scenes since they preserve metric information and structural coherence [22]. Previous studies suggest that serial order is more bound to verbal than spatial information in working memory [12], and that spatial information is strategically chunked in local spatial configuration [23]. Consequently, when encoding a spatial description, we can expect two main scenarios. On the one hand, the spatial description is encoded as verbal information and will then rely on the serial position order; in this case, it would be exposed more easily to serial position effects. On the other hand, if the spatial description is encoded as spatial information, it will be unbound to serial order and more prone to other organization strategies. Thus, if the spatial description is encoded as spatial material, we should expect a response to serial order different from that typically shown by verbal stimuli.

Concreteness is an important factor that typically affects the recall of verbal items in a serial order. Empirical evidence has demonstrated that concreteness and other features of the language, such as word frequency and lexical status, affect the number of items successfully recalled [24]. According to the authors, concreteness seems to foster memory processes since representations of concrete items contain more information than those of abstract items. In particular, concreteness strengthens item memories and consequently leaves time and resources available to process serial orders. This effect can be interpreted according to Paivio's dual coding theory [25], which assumes that concrete words maintain both a verbal and an imagistic code. Moreover, it is consistent with the idea that using different types of information sources leads to better performance [26]. The concreteness of the items might be enhanced by including them in a meaningful context; indeed, it has been demonstrated that items are better recalled in a meaningful context than in a list [27, 28]. According to Brodsky *et al.* [29], the logical structure which joins items seems to have a crucial role in organizing memory processes.

Based on our analysis, spatial coding and meaningful context are the two factors that might determine a different serial position effect for items encoded in a spatial description than in a word list. Indeed, the spatial description provides information relative to the spatial relations between the described objects. Moreover, the described objects are included in a meaningful context, enhancing the ability to visualize the described environment mentally. Therefore, both the spatial coding and meaningful context characterise the spatial description. In order to determine the "pure" influence of spatial coding on the serial position effect of items included in a spatial description, it is necessary to test the occurrence of the serial position effect on items described within a meaningful narrative, which provides no spatial information.

The present study aims to investigate the occurrence of the serial position effect in the recall of items verbally presented in three different contexts: a classic word list, a spatial description of a room and a narrative without spatial information. We expect different accuracy distributions across item positions for the three contexts. In particular, we hypothesise that the spatial description will be encoded as spatial material, reducing the influence of the serial order and consequently determining a flattened U–shaped curve. Moreover, we hypothesise that the accuracy distribution for the spatial description will be different from the accuracy distribution for the narrative without spatial information.

2. METHODS

2.1. Participants

Seventy–five university students (M = 19; F = 56) participated in this experiment in exchange for academic credits. Their age varied from 19 to 51 (M = 22; SD = 4.9). All participants were native Italian speakers. All participants reported that their psychophysiological state was not affected by alcohol consumption or insufficient sleep in the last 24 hr [30]. The participants signed the informed consent before starting the experiment. Participants were naive as to the purpose of the experiment.

2.2. Experimental Design

We employed an experimental design with two independent variables: Context (between subjects) and Position (within subjects). As regards Context, participants were randomly assigned to three conditions: List (L), Spatial (S), and Narrative (N). The Context variable refers to the context in which fifteen objects were verbally described in the learning phase. Indeed, in the List condition, participants listened to a list of fifteen objects; in the Spatial condition, participants listened to the description of a fictitious room containing the same fifteen objects described in the list; in the Narrative condition, participants listened to a meaningful narrative, in which the fifteen objects are described in a non–spatial context.

The Position variable refers to the position of the fifteen objects described in the three contexts. Indeed, the position of each object was kept unchanged across the three Context conditions. To effectively investigate the shape of the serial position effect, the variable position was rendered discrete with three levels. The fifteen objects were grouped into five clusters of three objects each. Then, the Initial condition refers to the first three objects (1–3), the Central condition refers to the three central objects (7–9), and the Final condition refers to the final three objects (13–15).

2.3. Material

To provide participants with auditory information (narratives description and testing trials), we employed a notebook connected with Sennheiser HD515 headphones. The same notebook, running E–Prime 2 Software, was used to generate trials and perform the task.

2.4. Stimuli Generation

We chose fifteen words that were comparable in terms of both frequency use in the Italian language and the number of letters. According to the experimental design, we manipulated the context in which the fifteen objects were presented. In the List condition, the fifteen words were presented in a sequence, as for example, “carpet, pillow, backpack, […]”. Differently, in the other two Context conditions, the same words were included in a verbal description. Specifically, in the Spatial condition, the words were included in the spatial description of a room. This kind of description included spatial coordinates for each object and the spatial relation between two subsequential objects, for example “at the right corner, above the carpet on the floor, there is a pillow and a backpack [...]”. Conversely, in the Narrative condition, the words were part of a story. This story described the objects in the room concerning their role in the narrative, rather than to spatial information, as for example, “I lie down on the carpet, leaning my head on the pillow and facing the backpack [...]”. The total number of words in the spatial description and narrative was analogous. In a pilot study, we tested the appropriateness of the descriptions provided. In particular, we tested the text comprehension difficulty in the spatial description and narrative; moreover, only for the spatial description, we asked participants to evaluate the ease in mentally representing the room described. The results confirmed the appropriateness of the description provided [1].

Both the list of words and the verbal descriptions were read by an experimenter and recorded. The time between two subsequent words was comparable across the three Context conditions to avoid any possible confounding effect of time.

2.5. Procedure

The experimental procedure consisted of learning, in which, depending on the condition, participants listened to the context (either in the list or in the descriptions), and a testing phase, in which participants performed an old/new recognition task.

Before beginning the learning phase, participants read and signed the informed consent. Then they were accompanied into a silent, dimly lit room, positioned comfortably on a chair in front of a computer, and asked to wear the headphones. The duration of the learning phase differed across the Context conditions, since participants were exposed to the fifteen objects described within three different contexts. In the List context, they listened to a serial list of the objects; in the Spatial context, they listened to a verbal description of objects with precise spatial coordinates; in the Narrative context, they listened to a story that featured each object in a narrative. Before listening to the contexts, in all the conditions, participants were asked to listen to the stimuli carefully and to memorize them. No information was provided to participants as regards the subsequent task.

The testing phase started immediately after the learning phase. As soon as the list or the descriptions ended, participants were asked to observe the monitor and read the instructions explaining the following old/new recognition task. The task required participants to decide whether the acoustically provided words were old or new by pressing two alternative keys on the keyboard. There were thirty words: fifteen of them were the names of new objects, and the other fifteen were the names of the objects previously heard in the learning phase. Participants were exposed to three repetitions of the words in random order. After each repetition, participants were allowed to take a little break. Both accuracy and response times were measured.

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[1] Fifteen participants were asked to evaluate the comprehension difficulty of both the narrative and the spatial description by using a 7–point Likert scale (1 meant “Not comprehensible” and 7 meant “totally comprehensible”). Mean scores of both the narrative (M = 6; SD = .84) and spatial description (M = 6.3; SD = .72) were statistically different from the central value of the scale and did not differ from each other. Similarly, the participants were asked to evaluate the ease in mentally representing the room (1 meant “very difficult” and 7 meant “very easy”). The mean score (M = 5.6; SD = .91) was significantly above the central value.

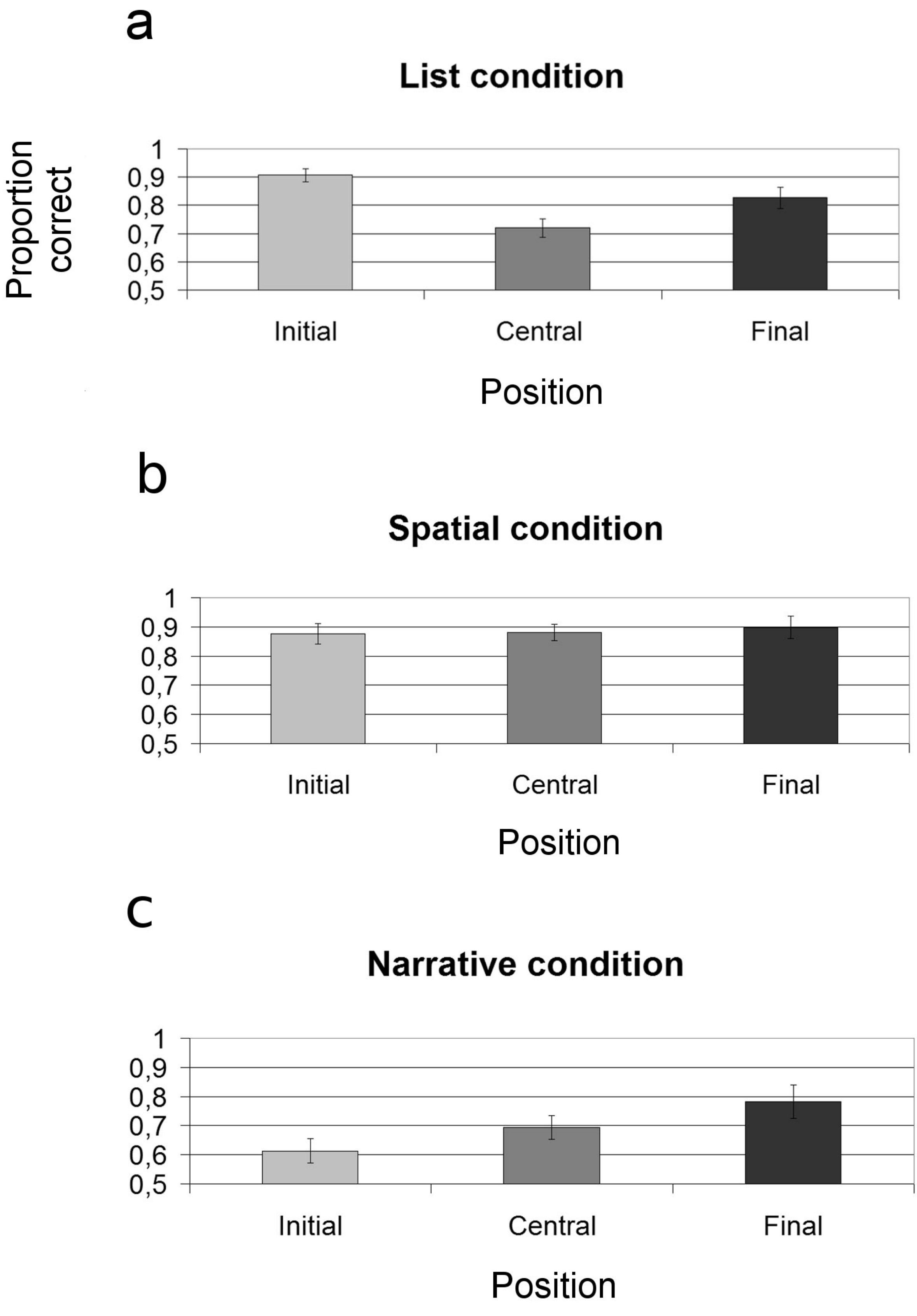

Fig. (1). Distribution of accuracy scores across item positions for the list (**a**), spatial (**b**) and narrative (**c**) conditions. Error bars indicate standard errors.

Since the experimental procedure combined different types of stimuli (*i.e.*, word lists and verbal descriptions), we could not employ the test procedures commonly adopted with one of the two types of stimuli, such as free or serial recall [31, 32] and story retell procedure 29, respectively. Free or serial recall would require participants to autonomously report all the words they can recall in a list format. This procedure would be adequate to measure accuracy in the List condition but could promote memorization if the items are in a list form, potentially suppressing any effect determined by the Spatial and Narrative contexts. Similarly, a story retelling procedure would be suited in the case of the Narrative condition, but it could as well promote a style of memorization that could suppress the effect of the Spatial and List contexts. To sum up, none of these procedures could be adequately applied to all three contexts. Therefore, to expose participants to the same test procedure in all conditions, we decided to employ a two alternative forced choice task [33 - 36].

3. DATA ANALYSIS AND RESULTS

We calculated the proportion of correct responses for each item and the mean scores between the items belonging to the Initial, Central and Final conditions for each participant. Since we were interested in testing the serial position effect depending on the context in which the items were described, we considered for analysis only the results obtained for the words presented during the learning phase, but omitting the data for the new words.

3.1. Accuracy

As regards accuracy, we performed a 3 x 3 (Context x Position) repeated measures ANOVA, revealing a significant main effect of Context [$F(2, 72) = 11.912$; $p < .001$; $\eta 2 = .249$], a main effect of Position, [$F(2, 144) = 3.505$; $p < .05$; $\eta 2 = .046$], and a significant interaction, [$F(4,144) = 5.658$; $p < .001$; $\eta 2 = .136$]. Planned contrasts with Bonferroni correction showed that participants were more accurate in the List and Spatial conditions than in the Narrative condition ($p < .001$ and $p < .005$, respectively), while the comparison between the List and Spatial conditions was only marginally significant ($p = .09$). Since the interaction reached a significant value, we ran further statistical analyses to understand the direction of the effect better; thus, we performed separate analyses for each Context condition (Fig. **1**).

As regards the List condition, a repeated measures ANOVA for Position showed a significant main effect, [$F(2,48) = 10.012$; $p < .001$; $\eta 2 = .294$]. Planned contrasts with Bonferroni correction revealed that participants were more accurate in the recognition of words in both the Initial and Final conditions than in the Central condition ($p < .001$ and $p < .05$, respectively), while no difference emerged between the Initial and Final conditions. Moreover, the statistics showed a significant quadratic trend, [$F(1,24) = 17.155$; $p < .001$; $\eta 2 =.417$].

As regards the Spatial condition, we performed repeated measures ANOVA for Position, which revealed neither a significant main effect nor a significant quadratic trend.

Finally, in the Narrative condition, we performed a repeated measures ANOVA for Position, finding a significant main effect, [$F(2,48) = 4.103$; $p < .05$; $\eta 2 = .146$]. Planned contrasts with Bonferroni correction revealed no difference either between the Initial and Central conditions or between the Central and Final conditions, while accuracy in the Initial condition was statistically lower than in the Final condition ($p < .01$). Moreover, no significant value was found for the quadratic trend. Instead the data revealed a significant linear trend, [$F(1,24) = 8.048$; $p < .01$; $\eta 2 = .251$].

3.2. Response Times

As regards response times, we performed a 3 x 3 (Context x Position) repeated measures ANOVA, which revealed neither significant main effects nor significant interaction.

4. DISCUSSION

In the present study, we aimed to investigate whether the occurrence of the serial position effect changes in the recall of items verbally presented in three different contexts. We expected different accuracy distributions across item positions for items described in the three contexts. In particular, we hypothesised a different accuracy distribution for the items when they were presented in the spatial description compared to the list and the narrative description. The results confirmed our hypothesis.

As for the accuracy scores, we found a significant influence of the context on the overall accuracy, with generally higher performances for participants in the spatial condition. Moreover, interesting results emerged when data was examined separately for each Context condition. Consistent with the serial position literature [3], participants who listened to the list of words showed a significant decrease in accuracy for items in the central position of the list, confirming the occurrence of the typical serial position effect for word lists. Furthermore, the quadratic trend further confirmed the occurrence of the serial position effect, as shown by the U–shaped accuracy curve.

Conversely, a different pattern of results was found for the Spatial condition. Indeed, the performance of participants who listened to the spatial description did not significantly change as a function of the position of the items, keeping a high accuracy score in each item position. The lack of the serial position effect might be due either to the meaningful context or to the spatial features; however, data from the narrative condition demonstrated that a meaningful context does not elicit the maintenance of high accuracy scores across item positions. Indeed, differently from the spatial description, the performance of the participants who listened to the narrative gradually increased as a function of the position of items, as confirmed by the significant linear trend. Therefore, we can attribute the high accuracy scores across item positions (and consequently the absence of the U–shaped curve) in the spatial condition to the spatial features of the verbal description.

As for the narrative condition, the linear increment in performance towards the last items differs greatly from the serial position effect usually observed in list recall. In this case, we observed no primacy effect, while the recency effect seems to be driving the observed trend. We could attribute this result to the nature of the narrative itself. Different from lists, in which each item is separated by a brief pause, in the narrative, the story is continuous and does not allow the participants to reiterate the first items heard. This lack of reiteration might account for the lack of primacy effect observed in this case.

As for response times, we did not find significant results. However, in the analyses of the serial position effect the role of response times seemed to be less important than that played by accuracy. Previous studies on the serial position effect focused mainly on accuracy scores, suggesting that accuracy might better stress the potential effects related to the serial order of items. Indeed, many studies did not even report the results of the response times [3].

Overall, the results of the present study indicate that the accuracy distribution is affected by the serial order of the items depending on the context in which the items are presented. Consistent with our expectations, the spatial description provides a spatial framework in which the objects are encoded, overcoming the cognitive limitations determining the serial position effect. Thus, our results are in line with the assumption that spatial descriptions are encoded as spatial information [19]. Indeed, the accuracy distribution after the exposure to spatial descriptions is similar to that found for visuospatial material in previous studies, showing weaker primacy and recency effects than for verbal stimuli [7, 12].

Thus, our data indicate that spatial descriptions are unbound to the serial order of the items and are more prone to other strategies of the organization, such as imagery strategies (see [37]). According to this interpretation, we might claim that the spatial descriptions behave like visuospatial stimuli, even though they belong to the verbal domain.

The performances obtained by participants while listening to the spatial description can be explained by the Dual Coding Theory [25], which postulates the occurrence of at least two coding systems, a verbal system and a non–verbal system. According to this theory, spatial descriptions might be coded by both the verbal and non–verbal systems, as they contain both a verbal and a non–verbal (*e.g*., visuospatial) characterization. Consequently, the spatial descriptions are memorized both in a verbal and a non–verbal form, causing the occurrence of two separate – but connected – memory traces. Similarly, although both systems should memorize the meaningful narratives (without spatial information), however, the different accuracy distributions of spatial descriptions and narratives could be attributed to the non–verbal system. Indeed, it is plausible that the spatial features of the spatial descriptions determine stronger visuospatial memory traces compared to those elicited by the narratives. Alternatively, our results can be explained by Johnson-Laird's Mental Model Theory [37, 38]. In this case, the spatial features of the spatial description determine a spatial mental model of the text [39], which is probably more effective than the mental model evoked by the narrative.

CONCLUSION

In conclusion, the present study provides evidence demonstrating that the effect of the serial order of items changes depending on the context in which items are described. Whereas the word list determined a decreased accuracy for central items, a linear performance increment (from initial to final items) was observed when items were described in a meaningful narrative. Conversely, accuracy remained stable at high levels when items were described spatially, suggesting that spatial descriptions are processed like visuospatial stimuli, even though they originate in the verbal domain. Therefore, our results align with the assumption that the verbal description of an environment could lead to the development of a spatial mental representation, which facilitates item memorization and reduces the serial position effect. Overall, these results add an important piece of information regarding the mechanisms based on the mental processing of described environments [40, 41].

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The present experiment was conducted with the approval of the University of Trieste Ethics Committee (minutes no. 101/2019).

HUMAN AND ANIMAL RIGHTS

No animals were used for studies that are the basis of this research. All the humans were used in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013 (http://ethics.iit.edu/ecodes/node/3931).

CONSENT FOR PUBLICATION

Informed consent for publication was provided by all participants.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available on request from the corresponding author [M.M].

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None.

CONFLICT OF INTEREST

The authors declare no conflicts of interest, financial or otherwise.

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Declared none.

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