Exploring the Spatial Gradient Effect

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July 13, 2020

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Abstract

We examined the limitations of the spatial gradient effect, or decrease in availability of objects/locations as a function of distance traveled. Across three experiments we used naming time probes to measure availability of an initial spatial location after varying the distance a protagonist traveled. The findings will be discussed in terms of the limit they place on memory-based explanations, and the need for dimensional information that is a part of situation-based explanations of comprehension.

Keywords: Spatial gradient effect, situation model comprehension, memory-based processing

Exploring the Spatial Gradient Effect

Readers must continuously update their representations of text in order to maintain comprehension. This process involves updating, discounting, and changing information so that their representation remains current. Within the view proposed by Zwaan and Radvansky (1998) whenever a reader encounters a shift, or changes in a dimension of the text (i.e. characters, goals, space, time) the past information becomes less active. There is extensive research on this spatial gradient effect in which participants are slower to retrieve previously mentioned objects after shifts in a character's space (e.g. Curiel & Radvansky, 2002; Morrow et al., 1987;1989; O'Rear & Radvansky, 2019; Pettijohn & Radvansky; 2018; Radvansky & Copeland, 2006; Rapp et al. 2006; Tamplin et al., 2013). However, when the literature is reviewed this linear spatial gradient effect is actually quite limited and only observed under highly controlled circumstances, such as exposing the reader to the spatial layout prior to reading, map memorization, traveling through virtual environments, and/or spatial task demands. These controlled circumstances may create a different memory structure for a spatial layout than just reading alone, which would have implications on memory access and response time patterns for elements of the spatial environment.

The *spatial gradient of availability,* or decrease in availability of spatial information as a function of spatial distance traveled by a protagonist, has been consistently demonstrated in many studies involving memorization or simulations of spatial maps (e.g., Bower & Morrow, 1990; Glenberg et al. 1987; Morrow et al., 1987; 1989). The spatial gradient effect was initially established by Morrow and Colleagues (1987; 1989). The consistent methodology has been first participants learn a building layout with various rooms and objects in those rooms. Once that map and the objects were committed to memory, assessed through various testing strategies, the participants would then read narratives about a protagonist moving from a source room, through a path room, to a current location room. Mental processing for spatial information was then assessed through reading time on critical sentences and/or probe verification. According to the theory of the spatial gradient of accessibility, objects closest to the protagonist in the location room should be more accessible than objects in the path room and source room. Additionally, accessibility should be greater in the path room than the source room since accessibility decreases as distance from the protagonist increases.

The spatial gradient effect has also been examined in virtual computer environments (see Radvansky & Copeland, 2016 for review of literature). Often in these experiments participants read about a protagonist moving through rooms and interacting with objects in the room (i.e., picking up objects, carrying various items, putting objects down, picking up new objects). At random times participants were asked to verify whether they held an object ("yes" response) or never held an object ("no" response). The consistent finding of this task has been that participants are faster to respond "yes" to currently held, or associated objects than objects they just put down, or dissociated

However, there are also studies that do not find evidence for the spatial gradient effect. For example, Tamplin et al. (2013) conducted a series of experiments meant to assess the spatial gradient effect and argued that their pattern of results was not consistent with the traditional view of the spatial gradient effect. Activation was confined to the current location and there was not a gradient pattern of availability based on distance. Further the authors argued that for narrative comprehension studies the pattern of the spatial gradient effect may be due to the processes and memory organization constructed by studying segmented map and subsequent retrieval of that memory structure. The organization of the at structure is based on multiple rooms, with multiple events, or segment, in a specific order. When in a virtual environment, participants can see surroundings, however when reading they must rely on their memory representation of the map which might create more of a segmented event-based memory structure during retrieval, which subsequently leads to a gradual spatial gradient effect.

Additionally, narrative literature (that does not include map memorization, or virtual computer maps) hasn't consistently found this increased processing time for spatial shifts (e.g., see Smith & O'Brien, 2012 for review), this has been interpreted as lack of updating for the spatial dimension, that is, a lack of evidence for the spatial gradient effect. Radvansky and Copeland (2010) argued that reading time measures may not be the best tool for spatial shift processing. When different measures are used there is evidence indicating that not only do people regularly update but spatial processing may be especially easy and require less mental effort.

The spatial gradient effect is limited and only observed when the reader is exposed to the spatial layout prior to reading, through map memorization, previously described environments, virtual environments, or spatially dependent task demands. These manipulations may create a different memory structure for a spatial layout than just reading alone, which would have implications on memory access and response time patterns for elements of the spatial environment, such as a decrease in availability of spatial information as a function of spatial distance traveled. These limitations to observed spatial gradient effects make good sense within memory-based models of reading such as the RI-Val model (e.g., O'Brien & Cook, 2016a; 2016b). Within the RI-Val model, as information from the reading is encoded, any relevant information from memory is reactivated through a passive resonance-like process which can include earlier portions of the text and general word knowledge. Next, any information that meets a minimum threshold of activation is linked with the contents of working memory during integration. These linkages are made based on general conceptual overlap (independent of whether they make sense or not) and then validated against the active contents of long-term memory (i.e., previously read text and general world knowledge). Previously memorized maps and virtual computer environments create a foundation for making spatial information highly accessible, or in focus. That spatial information is then more likely to be available and integrated with memory and the spatial gradient effect is observed. However, when there is no map, the reader relies on cues in the text (e.g., Smith & O'Brien, 2012), or additional task demands that would increase the readers focus on spatial information (Smith et al. in press). Therefore, it is important to understand how a spatial environment is encoded, organized, and retrieved during comprehension of text alone.

In the current experiments we attempted to further examine the limitations of the spatial gradient effect. In the following three experiments readers had no previous task demands, such as map memorization, virtual computer environments, and no prior knowledge of the spatial layout of the protagonist. We assessed spatial distance as a function of Euclidean distance and not the number of intervening rooms, which could serve as spatial cues to the reader and therefore influence spatial availability. Additionally, space and time are highly confounded, therefore we attempted to hold temporal shifts constant across different sized spatial shifts (Experiment 2). Finally, in Experiment 3 we assessed whether the spatial gradient effect was linear in nature by adding a third "no shift" condition (i.e., an initial location would be less accessible after a small shift than no shift, and even less accessible after a large shift). The linear nature of the spatial gradient effect has been heavily implied, however there has been little evidence to actually support a linear decrease in activation other than early map memorization work.

Method

Participants

Across three experiments there were a total of 78 participants who received partial course credit.

Materials

The materials consisted of 24 narrative passages. See Example Passage in Appendix A. Each passage was divided into four sections: an introduction, a shift manipulation, a probe, and a comprehension question. Each passage began with an introductory section that described a protagonist in a spatial environment. For half of the passages, this was followed by two sentences. The first shift sentence served to place the protagonist at source location. The second shift sentence described movement to a new current location. The location names were always the last word of each sentence. Following the second shift sentence, participants were presented with a probe word (always 4-5 characters) for the source location. All passages were followed by a comprehension question to ensure that participants were reading carefully.

Procedure

In all Experiment participants were run individually on a dell computer in a session that lasted approximately 35 minutes.

Results

In all analyses reported, F_1 always refers to tests against error terms on participant variability, and F_2 always refers to tests against an error term based on items variability. In Experiment 1, the naming times for the source probe were significantly faster after a small shift (M=504. 56, SD= 65.3) than after a large shift (M=517.85, SD= 63.2), F_1 (1, 22) = 5.59, *MSE* = 379.15, $p = .027$; F_2 (1, 22) = 8.37, *MSE* = 481.67, $p = .008$. As indicated by naming times, the source location was less available in memory after a large spatial shift compared to a smaller spatial shift.

In Experiment 2, consistent with Experiment 1, the naming times for the source probe were significantly faster after a small shift (M=509.17, SD= 64.65) than after a large shift (M=521.84, SD= 65), F_1 (1, 22) = 38.62, *MSE* = 49.92, $p < .001$; F_2 (1, 22) = 14.97, *MSE* = 387.13, $p = .001$. As indicated by naming times, the source location was still less available in memory after a large spatial shift compared to a smaller spatial shift even when time is held constant across conditions.

In Experiment 3, consistent with Experiments 1 and 2, the naming times for the source probe were significantly faster after a small shift (M=493.09, SD= 41.49) than after a large shift (M=513.14 SD= 41.15), F_1 (1, 27) = 47.59, *MSE* = 253.48, $p < .001$; F_2 (1, 27) = 13.39, *MSE* = 515.98, $p = .001$. For the no shift condition (M= 497.93, SD=42.8) naming time for the source probe was significantly faster than the large shift condition, F_1 (1, 27) = 17.16, *MSE* = 404.61, $p < .001$; F_2 (1, 27) = 10.24, *MSE* = 490.57, $p = .004$, however there was not a significant naming time difference between the no shift and small shift conditions, p= .230.

Discussion

In Experiments 1 and 2, naming times for the word "beach" were faster after a small shift than a large shift. However, in Experiment 3 when a control condition was naming times for the small-shift condition did not differ from naming times in the control condition.

Based on previous research (e.g. Tamplin et al., 2013) and memory-based models of text comprehension (e.g., O'Brien & Cook, 2016a; 2016b) we would have expected no reliable differences in availability following either a small shift or a large shift. Once the protagonist has shifted, prior location information is no longer in active memory; the amount of shift shouldn't matter. However, in the current experiments we consistently found that the initial spatial location of the protagonist was less active after a larger shift in distance than after a smaller shift in distance. Further, if there was a shift gradient that acted in a linear fashion then we would have expected naming times to be fastest in the control conditions, slower in the small shift conditions, and slowest in the large shift conditions.

The results of the current experiments provide evidence for an all-or-nothing decrease in activation, rather than a series of gradual decreases based on the size of the shift. In addition, the findings may indicate limits in memory-based explanations. However, an alternative explanation could be that spatial information is easily processed because it is part of our everyday general world knowledge. Therefore, when we encounter a spatial shift in text, without being provided a map or visual cues, our general world knowledge becomes more highly accessible in order to maintain comprehension.

References

Bower, G. H., & Morrow, D. G. (1990). Mental models in narrative comprehension. *Science*, 247, 44-48.

Curiel, J. M., & Radvansky, G. A. (2002). Mental maps in memory retrieval and comprehension. *Memory*, *10*(2), 113-126.

Morrow, D. G., Bower, G. H., & Greenspan, S. L. (1989). Updating situation models during narrative comprehension. *Journal of Memory and Language*, 28, 292-312.

Morrow, D. G., Greenspan, S. L., & Bower, G. H. (1987). Accessibility and situation models in narrative comprehension. *Journal of Memory and Language, 26,* 165–187.

O'Brien, E. J., & Cook, A. E. (2016a). Coherence Threshold and the Continuity of Processing: The RI-Val Model of Comprehension. Discourse Processes, 53(5/6), 326–338.

O'Brien, E. J., & Cook, A. E. (2016b). Separating the activation, integration, and validation components of reading. In Ross, B. H. (Ed.), The psychology of learning and motivation, 65, 249-276

O'Rear, A. E., & Radvanksy, G. A. (2019). Location-based prospective memory. Quarterly Journal of Experimental Psychology, 72(3):491-507.

Pettijohn, K. A., & Radvansky, G. A. (2016). Walking through doorways causes forgetting: Event structure or updating disruption? Quarterly Journal of Experimental Psychology, 69(11), 2119–2129.

Radvansky, G. A., & Copeland, D. E. (2006). Walking through doorways causes forgetting: Situation models and experienced space. Memory & Cognition, 34, 1150–1156.

Radvansky, G. A., & Copeland, D. E. (2010). Reading times and the detection of event shift processing. Journal of Experimental Psychology: Learning, Memory, and Cognition, 36(1), 210-216.

Rapp, D.N., Klug, J.L. & Taylor, H.A. (2006) Character movement and the representation of space during narrative comprehension. *Memory & Cognition* 34, 1206–1220

Smith, E. R., & O'Brien, E. J. (2012). Tracking spatial information during reading: a cue-based process. Memory & Cognition, 40(5), 791-801.

Smith, E.R., et al. (in press) Access to prior spatial information. *Memory & Cognition*

Tamplin, A.K., Krawietz, S.A., Radvansky, G.A. & Copeland, D.E. (2013). Event memory and moving in a well-known environment. Memory & Cognition, 41(8), 1109-1121.

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin*, 123(2), 162-185.

Appendix A

Example Passage

<u>Introduction:</u> Maria was an early bird and loved waking up early each and every morning. She arranged her schedule so she could have the morning off. She even got into a habit of going to bed early so she would wake up refreshed each morning. Watching the sun rise was her absolute favorite way to start each day.

<u>Shift Sentence 1:</u> This morning she was watching the sun rise at the *beach.*

<u>Shift Sentence 2:</u> **(Small Shift/Large Shift conditions):**

> **Experiment 1:** When it was over she drove the (1 mile/ 8miles) back to her house.*
>
> **Experiment 2 and 3:** When it was over she (walked/drove) for 10 minutes until she got home.*
>
> **Experiment 3 no shift condition:** When it was over she stood for 10 minutes looking at the sky.*

<u>*Naming time Probe:</u> *Beach*