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Abstract

Two experiments examined the hypothesis that constructing spatial representation and making inference from it with route description requires text continuity. Participants read the spatial text and answered true/false questions about it. In Experiment 1, we transposed sentences in a spatial text, and in Experiment 2, we inserted irrelevant tasks into a spatial text. The results showed that performance in a route perspective decreases when text has lost its continuity. This decrease in performance was not found in a survey perspective. These results indicate the continuous nature of route perspective, not only at the surface level of description but also at the level of cognitive processing.

Keywords: route perspective; survey perspective; spatial mental models, spatial representation, text continuity

Introduction

When we think about a space or when we are trying to follow directions, we construct spatial representations and infer spatial information from them. Taylor & Tversky (1992) defined two types of perspective in the input and output of spatial representation—route perspective and survey perspective. In route perspective, terms such as "front," "back," "left," and "right" are used to give directions from the perspective of an imagined viewer (e.g., "When you get out of the building, you can see a supermarket in front of you."). Survey perspective, however, includes terms such as "north," "south," "east," and "west" to give directions, taking a bird's eye view (e.g., "The building is north of the supermarket.").

Many studies have pointed out the difference between these two perspectives. Of specific importance to the present investigation, some studies (Pazzaglia & Cornoldi, 1999; Pazzaglia, Meneghetti, De Beni, & Gyselinck, 2010) focused on the two components of visuo-spatial working memory (VSWM) in route perspective. They divided VSWM into two components: the spatial sequential process and the spatial simultaneous process. Spatial sequential tasks require participants to recall the order of the stimulus presentation, while spatial simultaneous tasks require participants to recall the visual configuration of the presented stimulus (Pazzaglia et al., 2010). Their results showed that the spatial sequential process is more involved in processing route description, whereas the spatial simultaneous process is more involved in processing survey description. This implies that the ability to process information sequentially is an essential factor for descriptions in route perspective.

More support for this idea comes from a study using children with learning disabilities (Mammarella, Meneghetti, Pazzaglia, Gitti, Gomez, & Colnoldi, 2009). Children with nonverbal (visuo-spatial) learning disability (NLD), reading disability (RD), or no disability participated in the experiment. They listened to route, survey, and non-spatial descriptions. After that, they performed a verification task and a location task. Although their performance was no different in the verification task with the non-spatial description, children with NLD showed decreased performance on the verification task, especially with regard to the survey description. In the location task, children with NLD had decreased performance more on the survey than on the route description (though this difference did not reach significance). Mammarella et al. (2009) showed that NLD children can form mental models from route description. They indicated that this is due to the "serial nature of language" involved in the route perspective.

Previous studies have shown the importance of spatial-sequential ability in route perspective processing. This ability belongs to the participants, and not to description itself. Therefore, in this study, we focused on the nature of description that whether each sentence had strong connections between itself and the previous/following sentence. There are two reasons why we emphasized continuity of route description. First, in route description, the directional terms are relative. Therefore, it is important to be aware of where one has come from and which direction he or she is facing. If no attention is given to it, one can easily get lost because the directional terms must be defined in relation with the imagined viewer. Second, the subject of the route description is "you." In addition to actually moving around, the subject of the description cannot warp to a distant place. They must move step by step, continuously.

In this study, we focused on the text continuity itself. Our hypothesis was that effective route description requires text continuity. If route perspective description is truly continuous, sentence order (i.e., text continuity) is important for it. In contrast, survey perspective does not need continuity and sentence order is less important. We manipulated the text continuity in two ways. In Experiment 1, we changed the order of sentences in a spatial text, while in Experiment 2, we inserted an interference task into a more complex spatial text. The novel point of this study is that we focused not on the traits of participants (Brunyé & Taylor, 2008b; Pazzaglia, et al., 2010), but on the traits of the text.

Experiment 1

In Experiment 1, we tried to examine the effect of continuity of sentence order on comprehension of route description. Although previous studies (Pazzaglia & Cornoldi, 1999; Pazzaglia, et al., 2010) have shown the importance of the spatial-sequential ability of learners in processing route description, the effect of the sentence itself has not examined. If the processing of route perspective is actually continuous, a sentence in the description must be connected to the previous and following sentences. Therefore, when this connection is broken, one faces considerable trouble learning information from route descriptions. We did not expect this effect in survey learning, because survey perspective is simultaneous and not sequential (Pazzaglia et al., 2010).

Method

Participants 35 Japanese graduates and undergraduates (19 males and 16 females) participated in Experiment 1 for a monetary reward. Mean age was 22.5 (range 18-28, *SD* = 2.6). We excluded three males from the analysis for not following instructions. Half of the participants studied all descriptions in the survey perspective, and the rest in route perspective.

Experiment design The design was 2 × 2 × 2 with learning perspectives (survey vs. route) as a between subjects factor, text continuity (continuous vs. discontinuous), and test perspective (survey vs. route), as within subjects factors.

Materials Twenty-eight spatial texts were prepared. Each text consisted of four sentences and described one environment where four landmarks (landmarks A, B, C, and D) appeared along a straight road. The first sentence referred to the position of one landmark (landmark A) in relation to the road. The second sentence referred to the spatial relationship between landmarks A and B. The third and fourth sentences referred to the relationships between landmarks B and C, and landmarks C and D, respectively. In discontinuous condition, the order of the third and fourth sentences was reversed. Therefore, he third and fourth sentences referred to the relationships between landmarks C and D, and landmarks B and C, respectively.

Each text had six verification tasks that asked about the relationships between two landmarks. Half were correct descriptions and the rest were incorrect.

Procedure We instructed participants to read the spatial text as fast as possible. After participants had finished reading the text, they answered true/false verification tasks about the environment that they had just learned about. Continuous and discontinuous texts were presented in random order. Halfway between the trials, participants took a rest. All stimuli were presented on a PC screen.

Results

Trials that included reading time beyond ±2 SD or under one second were excluded from the analysis below. According to this criterion, 77.7% of all trials were used.

Fig. 1 shows the accuracy of the verification question, which asked about the spatial relationships between the landmarks appearing in the third sentence. We chose only the third sentence because it is the initial sentence that differs according to the text continuity. In both continuous and discontinuous condition, the first and the second sentence are same.

The results of ANOVA showed a significant interaction (F (1, 30) = 4.997, p = .03, η_p^2 = .14) between text continuity × test perspective. All other interactions did not reach significance. In the survey test conditions, the accuracy did not show a significant difference (F (1, 30) = 1.400, p = .25, η_p^2 = .05). In the route test conditions, however, the accuracy was higher in the continuous condition than the discontinuous condition (F (1, 30) = 4.608, p = .04, η_p^2 = .13). In addition, the accuracy was higher in the route test condition than in the survey test condition when text was continuous (F (1, 30) = 10.343, p = .00, η_p^2 = .26). This difference, however, was not found in the discontinuous condition (F (1, 30) = 0.146, p = .70, η_p^2 = .00).

Discussion

As we predicted, the accuracy was higher in the continuous condition than in the discontinuous condition when participants used route perspective during the test. In contrast, performance did not show significant difference between continuous condition and discontinuous condition when they used survey perspective during the test. These results show that participants need text continuity when they recall spatial representation in route perspective. When participants recall the spatial relationships, they rely onto spatial representations which they had constructed before.

And whether the construction of the spatial representation was continuous or discontinuous, affect the spatial representation itself.

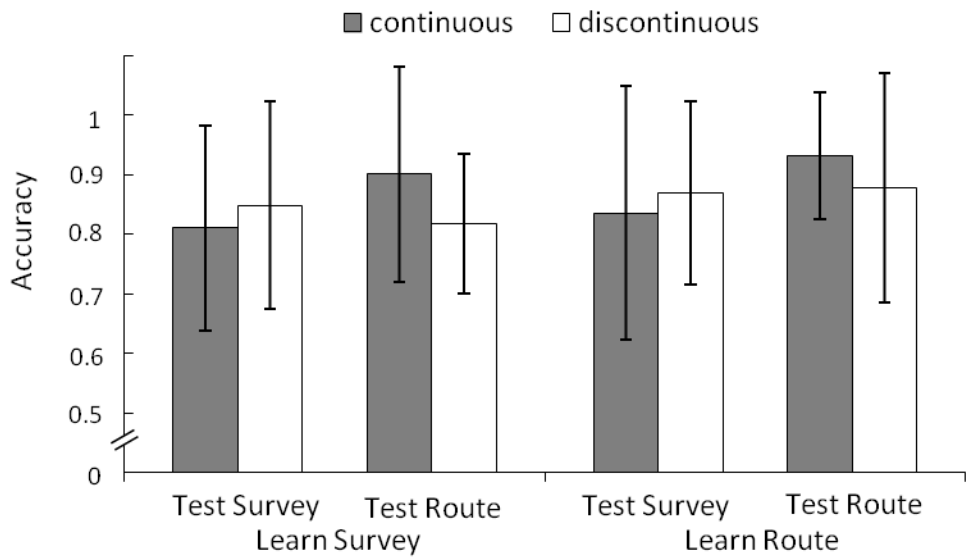

Fig. 1: Mean accuracy to the questions about the third sentence in Experiment 1 (bar means *SD*)

These differences however, appeared according to test perspective but did not according to learning perspective. This is not in line with our prediction. Although text continuity was a factor in learning, the performance differed according to the test perspective, rather than the learning perspective. We can think, however, that learning perspective has some effect on spatial representation. If spatial representations were the same regardless of learning perspectives, these differences would not appear because text continuity affects before the construction of spatial representation, not after. Therefore, constructed spatial representations should differ by the time participants construct it. One possible idea is that some factor lacks when participants learned the text in discontinuous conditions. They have to recall spatial information without the factor. When they recall in route perspective, the lack of the factor is make participants to have trouble in recall. When participants recall in survey perspective, however, the feature of survey perspective covers the lack of the factor. It is possible the factor is continuity of spatial representation.

One puzzling result is that participants showed better performance in route test than in the survey test when text was continuous. Previous studies showed superiority of survey perspective than route perspective in performance (Brunyé & Taylor, 2008a; Brunyé & Taylor, 2008b, Shelton & Gabrieli, 2002). We could not find this superiority of survey perspective in Experiment 1. There are two possibilities account for this tendency. One is that sentence order continuity works as a facilitator for route perspective, not that sentence order discontinuity works as an inference for route perspective. The other is that the studied environments were too simple. It is possible that in a simple environment, participants need not to form abstract spatial representations, and it covers up the difference in learning perspective.

To solve these problems, in Experiment 2, participants studied a more complex text than that of Experiment 1. A complex text makes participants better infer spatial relationships according to their spatial representations. Therefore, the verification task would reflect their spatial performance more accurately.

Experiment 2

In Experiment 2, as in Experiment 1, we examined the hypothesis that effective route description requires sentence continuity. We used the spatial texts used in Taylor & Tversky (1992). These texts were more complex than those used in Experiment 1, and participants had to make an inference about the environment. We manipulated text continuity by inserting irrelevant questions into the text. In the continuous condition we inserted short tasks that did not relate to the main text, yet still made participants conduct spatial inferences (such as “How many windows do you have in your room?” or “Which city is in the north, Kyoto or Nagoya?”). In the discontinuous condition, we inserted a simple counting task not to let participants rehearsal the text (“200 – 7 =?” or “100 + 8 =?”).

We made two predictions about the results. First, when participants learned the text from a survey perspective where the text did not need to be continuous, recall performance did not differ between the two conditions of text continuity. However, when participants learned text from a route perspective where the text does need to be continuous, performance did differ between the two conditions.

Method

Participants 67 Japanese graduates and undergraduates (34 males and 33 females) participated to Experiment 2 for a monetary reward. Mean age was 21.1 (range 18-25, *SD* = 1.8). 33 participants (17 males and 16 females) studied all descriptions with a survey perspective, and 34 (17males and 17 females) studied all with a route perspective.

Experiment design The design was 2 × 2 × 2 mixed, with learning perspectives (survey vs. route) as a between subjects factor, with text continuity (continuous vs. discontinuous) and test perspective (survey vs. route) as within subjects factors.

Materials Three tasks were conducted. Spatial text learning, Corsi blocks (Corsi, 1972) and the pathway span test (Mammarella, Cornoldi, Pazzaglia, Toso, Grimoldi, Vio, 2006). All tasks are conducted on the PC screen.

We used two spatial texts (town and convention center) from Taylor & Tversky (1992). Each text described an environment from two perspectives—survey and route. Each text had 28 True/False verifications: four questions were non-locative recognition, four were non-locative paraphrased, four were survey recognition, four were route recognition (survey and route recognition questions required inferences when study perspective and test perspective differed), six were survey inference, and six were route inference. In each category, three statements were true and the rest were false.

When participants learned the text, we inserted irrelevant tasks in every three sentences. In discontinuous condition as an experimental condition, we inserted spatial questions which are irrelevant to the main spatial text. Participants had to infer spatial relationships or to recall spatial alignment of objects which does not appear in the main text. We instructed participants to answer in five seconds. After five seconds passed, they return to the learning of the main text independently of the fact they answered to the inference questions or not, and the answer is correct or not.

In continuous condition as a control condition, we inserted simple counting tasks. We used counting tasks to prevent participants from rehearsal of the main spatial text. We instructed participants to repeat answering by five seconds passed (e.g. 93, 86, 79 …). After the five seconds passed, they return to the learning of the main text.

In the Corsi blocks task, participants memorized the order of the position where a dot appeared. The number of stimuli in one trial was from four to seven, and there were twelve trials. This task measured spatial-sequential ability. Studies have found positive relationships between this task and route perspective performance (Mammarella et al., 2006; Pazzaglia & Cornoldi, 1999; Pazzaglia, et al., 2010).

In the pathway span task, participants were told to follow movement in a five by five matrix according to the direction instructions. The number of instructions in one trial ranged from four to seven, with twelve trials in total. This task also measured spatial-sequential ability.

Procedure

First, participants conducted the Corsi blocks task. Then they were allocated to either the survey study condition or the route study condition, as performance on the Corsi block task did not differ between conditions. Next, participants read two spatial texts. One text was read for the continuous conditions and the other for the discontinuous conditions. After they read one spatial text, they answered 28 true/false questions about each text. Finally, they conducted the pathway span test. All stimuli were presented on a PC screen.

Results

One male was excluded from the analysis because he did not follow instructions. Another male was excluded because his verification performance in one condition was much lower (19.4%), although chance level was 50%. Both of them studied in the survey perspective. Verbatim questions that included reaction times beyond ±2 SD were excluded from the analysis. According to this criterion, 97.0% of all trials were used.

Fig. 2 shows the accuracy of the verification task where participants needed spatial inferences. The results of the ANOVA showed a marginally significant interaction between text continuity × test perspective (F (1, 65) = 3.769, p = .06, η_p^2 = .05). In the continuous condition, the accuracy in survey and route condition did not showed significant difference (F (1, 65) = 0.219, p = .64, η_p^2 = .00). In the discontinuous condition, participants showed lower accuracy in the route test than in the survey test (F (1, 65) = 5.614, p = .02, η_p^2 = .08). In the survey test condition, the accuracy in the continuous condition and discontinuous condition did not showed significant difference (F (1, 65) = 0.663, p = .41, η_p^2 = .01). In route test condition, participants showed lower performance in the discontinuous condition. The effect size of this difference is not small. This difference, however, did not reach to significance (F (1, 65) = 2.428, p = .12, η_p^2 = .04). We conducted ANCOVA which controlled for the scores either Corsi blocks task or pathway span test or both of them. Those analyses, however, showed no statistical significance.

Discussion

As predicted, when text lost its continuity, participants in the route test condition decreased performance compared to the survey condition. Our hypothesis that route description requires text continuity was partially supported in Experiment 2. The discontinuous text lowered the accuracy when participants were tested in the route perspective. The effect was, however, limited and some predicted results did not reach to significant level.

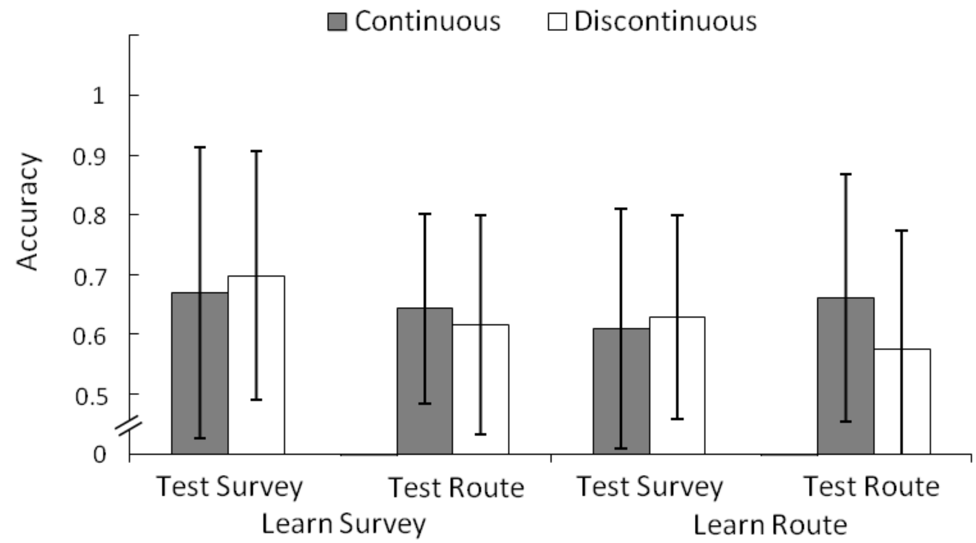

Fig. 2: Mean accuracy to the spatial inference questions in Experiment 2 (bar means *SD*)

As in the Experiment 1, the effect of text continuity appears according to the test perspective. We have a good reason, however, to believe text continuity affect how we learn the spatial information as we stated in the discussion of Experiment 1.

Previous research (Pazzaglia & Cornoldi, 1999; Pazzaglia, et al., 2010) has shown the importance of the spatial-sequential ability of learners in processing route description. This study shows that not only the spatial-sequential ability of the readers but also the text continuity itself is important to route description. This result reveals the more continuous nature of the route perspective than the survey perspective. In route description, it is clear that one must remember from where he or she has come, and which direction he or she is facing. The result of this study indicates that text continuity is essential, not only to description itself but also to the mental processing of route description.

General Discussion

We conducted two experiments and examined the effect of text continuity in route perspective. In Experiment 1, we manipulated text continuity by transposing the sentences. In the test phase, text continuity increased performance of the route perspective. In Experiment 2, we manipulated the continuity by inserting irrelevant tasks into the more complex spatial descriptions than Experiment 1. Performance on the route test decreased in the discontinuous condition where participants inferred spatially. These results support our hypothesis that route perspective needs text continuity.

Previous studies have found that spatial sequential ability is necessary for learning route description (Pazzaglia & Cornoldi, 1999; Pazzaglia, et al., 2010). In this study, we found that not only spatial-sequential ability but also text continuity is essential for understanding route descriptions. This dependence on continuity seems to relate to the nature of route description, as readers must continuously update changes in their local environment (Shelton & Gabrieli, 2002).

This study revealed that text continuity affects the retrieving of spatial information in route perspective. It remains unrevealed, however, when text continuity affect route perspective. There can be two possibilities about it. There was a significant interactions between test perspective $\times$ text continuity. There is no doubt, therefore, text continuity affect at the test. In this case, spatial representation formed in discontinuous condition lacks continuity regardless of the learning perspective. When one uses route perspective to retrieve information from that discontinuous representation, a problem occurs. He or she can’t rely onto continuity of the representation, has to navigate in his/her spatial representation discontinuously and the performance decreases. When one uses survey perspective at the test, whether the spatial representation is continuous or discontinuous does not matter. He or she can successfully retrieve information from his/her spatial representation even when it is discontinuous. Although the interaction between study perspective and text continuity was not statistically significant, this does not necessarily denies the possibility of the effect of text continuity at learning. It is possible that the effect of text continuity at learning exists, however, is too weak to affect at the learning.

We refer to three remaining problems in this study. First, we used spatial text to present stimuli to participants in this study. Text and languages are naturally continuous and the results of this study might appear only when one studies one's environment using language. Therefore, we must confirm these results through other forms of studying, such as navigation in reality or watching videos involving specific locations. Second, we have to solve problems about the types of two inference tasks in Experiment 2. We regarded spatial question as an inference task and counting tasks as a control one. This distinction, however, is relatively arbitrary. It is possible that these tasks differed in types of inference, not in continuity. To solve this problem, we may need another control condition which is different from ones in continuity. In addition to that, forming spatial representation and extract information from that is quite complex process and are thought to be affected by individual difference. Participants take many strategies and their abilities differ quite a large way (Kato & Takeuchi, 2003). Therefore, it is possible that individual difference and strategy preference affect the results and covers up the effects of some factors. In Experiment 2, almost all results showed the same directions with the predictions. The statistical analysis, however, showed only few of them. Therefore, the next step is to take into account individual difference and the strategy preference.

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