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Spatial information and visuospatial memory: Are the location of an object (WHERE) and the motion of an object (HOW) processed as the same module in spatial memory?

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This study examined whether two types of information (location and motion) were processed as the same module in spatial memory. In this experiment, the selective interference paradigm, consisting of primary tasks and secondary interference tasks, was used. When participants were asked to retain location information and to carry out the secondary perceptual task (location) during the retention interval, the memory performance was deteriorated more than to carry out the secondary motion task. Similarly, when they were to retain motion information, the memory performance was severely interfered with the secondary motion task. These results suggested that even though these two types of information were considered spatial information, location information and motion information were independent of each other.

Keywords: spatial memory, location information, motion information, selective interference paradigm

Research background and objectives

In the study of visuo-spatial memory, it has been demonstrated that visual objects (i.e., visual information) and objects in the space (i.e., spatial information) are two distinct information and, therefore, are not processed in the single memory system (e.g., Baddeley & Lieberman, 1980; Logie & Marchetti, 1996; Tresch, Sinnamon, & Seamon, 1993). Visual information involving the visual identification of objects such as shape and color is stored in visual memory, whereas spatial information that involves the spatial relationships among objects (the configuration and location of objects) is stored in spatial memory (Pickering, Gathercole, Hall, & Lloyd, 2001). Della Sala, Gray, Baddeley, Allamano, and Wilson (1999) have found that a visual interference task composed of viewing abstract paintings produced a much greater decrement in performance on a visual task (the visual patterns task) than a spatial interference task involving spatial tapping. Furthermore, Logie and Marchetti (1991) found that a visual interference task (the presentation of irrelevant pictures) and a spatial interference task (involving unseen arm movements) presented during a 10-s retention interval resulted in a significant decrement in performance only on a primary task of a similar kind.

In the studies of the perception and memory, stimulus attributes such as shape and color are often called “WHAT,” and the location is called “WHERE” (Ungerleider & Haxby, 1994; Pickering et al., 2001). However, spatial information should involve not only the location of stimuli, but also the motion of an object (“HOW”) processed in spatial memory since it moves in space and does not require a perceiver to attend the stimulus attributes when he or she tries to encode and maintain it. Although these two types of information are equally usable in investigating both the existence of two memory systems (i.e., visual and spatial memory) and the mechanism of spatial memory, spatial location is more often used in these experiments.

As mentioned above, a number of studies exist to suggest independent systems of memory for dealing with spatial information (such as the location of an object) and visual information (such as appearance). Although these two types of information are demonstrated as mutually independent information, it is not specified whether the location of an object, which is a static stimulus in the space, and the motion of an object in the space are really the same property of spatial information.

The type of stimuli used in the experiments in revealing the mechanism and functions of spatial memory are mostly the location of an object or a configuration of objects -that is, “WHERE” stimulus. For instance, using a change-detection task, Chun and Jiang (2000) had the participants memorize seven or eight items presented randomly on the screen, and after the short period of time, they were again presented previously seen items. An item was enclosed with white box. The task was to decide whether this target was positioned at a previously empty new location, or a previously occupied old one. From the experimental results, they argued that spatial memory does not represent scattered individual items, but it represents relational information (i.e., configuration) between items.

Is there any experiment that the motion information (HOW) – the other spatial property – has been used to investigate the mechanism of spatial memory? Smyth and Pendleton (1989) described that body motion like copying limb movements of others is considered appropriate experimental materials for the investigation of spatial memory. However, in their experiments, they found intriguing results that copying limb movements (motion task) and a tracking task like the Corsi blocks test (spatially tracking task) were independently retained. The participants tried to retain the body movements of a model as the primary task and, during the interval, performed the Corsi blocks test as the secondary task, but the recall and reproduction of limb movements were not interfered by the secondary task. Although these two types of information are spatial property, the fact that they are not interfered with each other contradicts the hypothesis that information is interfered with information of a similar kind. One explanation for this result is that the Corsi blocks task is similar in nature to location information so that it did not interfere with motion information like limb movements. Thus, it may be true that motion information is only interfered with motion information and that location information is only interfered with location information. Another explanation may be that although body motion involves the element of “HOW” property, this type of task is not purely spatial information because the participants try to not only recall but also reproduce the movements of the model.

There is a fundamental question: Are “WHERE” and “HOW” information processed and stored as the same property in spatial memory? In other words, are they encoded and retained as the same module? This question was investigated by Loeches, Valdes, Gomez-Jarabo and Rubia (1998). They examined whether "WHERE" and "HOW" are independent of each other. In their previous experiments, using an ERP paradigm, they had found different ERP modulations between spatial and visual information during the retention period. In this experiment, they tried to find out whether the ERP modulation of location is different from that of motion. A pair of flashed stimuli (S1), centered 0.7 degree away from the first flash in both properties, was presented at one of 4 corners on the screen. In the location condition, participants were presented S1, and after the short period of time, they were presented the second pair of flashed stimuli (S2). At the recognition phase, participants were to decide whether S2 was presented at the same corner. In the motion condition, S1 was presented at one corner, and after the interval, S2 appeared. At the recognition phase, they were to decide whether the direction of a second flash of S2 was the same as a second pair of S1. the results showed that there was not a distinct ERP modulation for the retention of motion information.

Loeches and his colleagues (1998) had to make the task simple in order to examine the differences of ERP. However, with only the ERP paradigm consisting of only simple tasks, it may not be sufficient to conclude that location information and motion information are the same module.

In my experiment, the selective interference paradigm (e.g., Baddeley & Logie, 1999) was employed to see whether these two types of information are the same module or not. In what case can we conclude location and motion are independently encoded and maintained? When a performance of the primary "HOW" task is more interfered with a suppressing "HOW" task than a suppressing "WHERE" task, and when a performance of the primary “WHERE” task is more interfered with the suppressing “WHERE” task than the suppressing "HOW" task, we may say these two types of information are independently retained.

Method

Seven undergraduates (6 males) and three graduates (1 male) were participated in the experiments. Stimuli were presented on the monitor screen connected to Audio – Visual tachistoscope (IS – 702).

In both “WHERE” and “HOW” tasks (both primary and suppressing), white squares (20 x 20 pixel) were presented in 6 x 6 matrix (240 x 240 pixel), and the distance of two squares was 40 pixels from their centers.

Seven or eight squares were randomly placed in each cell in the primary “WHERE” task. The time for the presentation was 3500ms (seven squares) and 4000ms (eight squares). In the primary “HOW” task, seven or eight cells were also used for apparent motion. The time for the presentation was the same as the primary “WHERE” task.

The suppressing “WHERE” and “HOW” tasks were almost the same as their primary tasks, but only seven squares were used in the suppressing task. A mask stimulus (randomly drawn lines on 6 x 6 matrix) was also employed.

There were six conditions in this experiment: 1) the primary “WHERE” task + no suppressing task, + suppressing “WHERE” task, + suppressing “HOW” task, 2) the primary “HOW” task + no suppressing task, + suppressing “WHERE” task, + suppressing “HOW” task.

Each condition consisted of 72 trials (70 for experimental trials + 2 for practice trials). In the primary “WHERE” task + no suppressing task, randomly located squares were presented, and participants were asked to retain the configuration. After the presentation of a mask stimulus (5500ms), the matrix appeared, and a probe square was shown in a cell. The participants were told to press “1,” if they think the probe was located at the same position in which they had previously seen. If not, they pressed “5” in the key unit. In the primary “HOW” task + no suppressing task, they retained a randomly moving square. The time for the presentations of apparent motion and of a mask stimulus were the same as the above condition. After the presentation of a mask, the matrix appeared, and a probe square was shown in the cell. The participants were told to press “1,” if they think the previously seen motion passed on the probe. If not, they pressed “5.”

In the case of either primary task + suppressing task, during the retention of either location or motion, participants had to perform suppressing task. After the presentation of either primary task, a mask stimulus was presented for 1000ms and was followed by the matrix for 3500ms. In the matrix, seven squares were randomly placed, and one of the squares flashed for 100ms in the half of trials. When the participants perceived a flash, they were told to press any key (1 to 5) in the key unit (suppressing task). After the completion of the suppressing task, a mask stimulus was presented for 1000ms, followed by the presentation of a probe square.

In either primary "WHERE" or "HOW" task + the suppressing "HOW" task, after the presentation of the primary task followed by a mask stimulus (1000ms), the matrix showed up for 3500ms. In the matrix, apparent motion consisted of seven squares moved in random directions, and when the square moved on any line consisting a matrix, not inside the cell, the participants were told to press any key (1 to 5) in the unit (suppressing task). After the completion of the suppressing task, a mask stimulus and a probe square followed.

Results

Figure 1 indicates the percentage correct of recognition. The scores were analyzed with a 2 (primary task) x 3 (secondary task) within-subject ANOVA. The main effect of primary task was not significant ($F < 1$, NS). However, the main effect of suppressing task was significant, $F(2, 18) = 4.32$, $p < 0.05$ (see Table 1), and the interaction, $F(2, 18) = 14.16$, $p < 0.01$ (see Table 1). As seen in Figure 1, a performance of the primary task without suppressing task was higher than any other condition.

As expected, the performance of the primary "HOW" task was more interfered with the suppressing "HOW" task than the suppressing "WHERE" task. Similarly, the performance of the primary "WHERE" task was more interfered with the suppressing "WHERE" task than suppressing "HOW" task.

Using multiple comparisons, the experimenter found that the difference between suppressing "HOW" and "WHERE" tasks was significant when the simple main effect of suppressing task on the primary "HOW" task was analyzed ($MSe = 15.0823$, $p < 0.05$). Furthermore, when the simple main effect of suppressing task on the primary "WHERE" task was analyzed, the difference between no suppressing task and the suppressing "WHERE" task was significant, and the difference between the suppressing "HOW" task and the suppressing "WHERE" task was also significant ($MSe = 15.1314$, $p < 0.05$) .

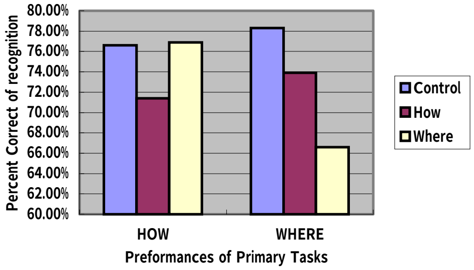

Figure 1. The performances of primary tasks with and without suppressing task

Table 1. Analysis of Variance for Primary Task and Secondary Task

Source	SS	df	MS	F
Subjects (S)	1740.417	9	193.38	21.9
Primary task (A)	30.817	1	30.817	2.12
(S) x (A)	130.683	9	14.52	1.64
Secondary task (B)	184.3	2	92.15	4.32
(S) x (B)	384.033	18	21.335	2.42
(A) x (B)	250.033	2	125.017	14.16
(S) x (A) x (B)	158.967	18	8.831	
Total	2879.25	59		

Discussion

These results were consistent with the experimental hypothesis that location and motion were not retained as same module. Since no-suppressing task did not differently affect performances of primary tasks, *the different types of information* were the factor that influenced the performances of primary tasks.

However, there is a problem with this experiment; that is, participants received a matrix as a reference frame. Would it be a problem? There was a possibility from this fact that the frame became a cue making the participants retain location and motion more easily. For instance, in the primary "WHERE" task, because of each square was placed inside a cell, participants could have imagined a matrix and inserted squares into appropriate cells in the mind during the retention period. In the primary "HOW" task, because participants had the frame, they knew where a moving square started and stopped. As a result, they were only to remember 5 or 6 flashed ones, ignoring start and stop squares.

Moreover, because of a reference frame participants may have retained the positions of cells where a moving square flashed, instead of a motion. The fact that a performance of the primary "HOW" task was similar to that of primary "WHERE" task indicates that motion information was retained as location information, suggesting these results may not show the different module of location and motion. Thus, it is necessary to eliminate the frame, and motion should be perceived and retained as "motion." If it is true that difference between performances of primary tasks with or without suppressing task were not based on the different types of information, then why didn't the suppressing "WHERE" task influence the primary "HOW" task like it influenced the primary "WHERE" task? Perhaps, it is because "HOW" task required a sequential process, but "WHERE" task did not. These two questions should be dealt with in future experiments.

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