Method of Loci in VR Web Search: Memory Retention Support by Organizing Search Results in a VR Room

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Abstract. This paper investigates whether the *Method of Loci* is also effective for Web search in a VR environment. The *Method of Loci* (often called Mind Palace) is one of the most famous Mnemonic; when memorizing things, placing them in a building reproduced in the brain makes them easier to recall. We implemented a browser that is movable within the VR space, and VR rooms to verify whether such a Mnemonic could be used for Web searches in VR. The subject experiment compared four types of rooms: a Sequential-alignment room, a White room, a 4-colored wall room, and a Realistic room with furniture. In each VR room, users can freely create Web browser windows, and they can place, scale, tilt, and manage the windows anywhere in the room. Six participants searched for many things, compared them, and decided on their opinions in the VR room. The result shows that participants who searched in realistic rooms remembered more details of their searches a week later.

Keywords: Virtual Reality · Web Search · Information Retrieval · Method of Loci.

1 Introduction

With the rapid spread of VR (Virtual Reality) devices in recent years, opportunities for work to be performed in the VR space have increased. In addition to its original use for general game purposes, in an increasing number of cases, it is being used for practical software projects, such as construction use, events, and experience-based training. VR has the ability to work even if the object itself is not in that location, can return it to its original state immediately in case of failure, and checks the results in a three-dimensional way. The use of VR is progressing in a wide range of fields, such as education and training VR, since it can also be used for training where there would otherwise be the risk of physical danger.

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Despite the VR space being so convenient and experience-based, unlike work performed on a conventional computer screen, it has the disadvantage that it is challenging to search while working. For example, when searching during VR work, it is sometimes necessary to remove one's head-mounted display and search using a separate computer or smartphone. Moreover, even if the search takes place without removing the headset, it is necessary to close the software the worker was using and launch a search browser. Even if the search function is embedded within the VR space, it is necessary to input text and search in the VR space, where it is difficult to carry out the input process. Although, in reality, it is possible to search on the spot using a smartphone or PC, current VR technology has not yet developed to a state where it is possible to search with any level of comfort.

Several measures of resolution have been considered for resolving these kinds of issues relating to the difficulty of searching within the VR space. If we focus on complex issues surrounding the input of text, innovation regarding the following is required:

- Reducing the effort of input,
- Reducing the frequency of text input, and
- Reducing the number of searches itself.

We can broadly categorize these into two approaches: reducing the effort required for input and making repeat searches unnecessary. Many studies have focused on the approach of reducing the effort for input in the VR space and making text input a more comfortable process [1, 4, 11]. These include, for example, keyboards that make use of hand tracking [6]. With a software keyboard that uses the pinch input format, a circle is made using the thumb and other fingers, and this corresponds to the keyboard layout. With this format, as the software displays vocabulary after judging the context, this enables text entry at a low cost but has the feel of predictive text conversion. Methods have also been conceived that can reduce the frequency of text input by using information search technology, such as query recommendations. This kind of technology is not limited to the VR space, and is commonly used for search engines in mobile devices with complex text input.

On the other hand, however easy it is to enter text and however much the effort of inputting text is alleviated, it does not change the fact that it is necessary to suspend work to search while experiencing VR. The approach taken in this study is to reduce the number of searches. The objective of conventional methods has been to make input more comfortable when searching. On the other hand, if the number of searches themselves can be reduced, this could provide an indirect solution to the complexity of searching in a VR environment. It has been said that in Web searches carried out until now, most search queries are repeat searches of information that has already been searched before. According to a survey by Teevan [12], 40 percent of queries are repeat search queries. If we can eliminate repeat searches, there will be an opportunity to perform complicated procedures may be reduced by up to 40 percent, even if the text input and search procedures are complicated in a VR environment.

In this study, therefore, we propose a method in which, by allowing the search results to stay longer in the memory, we can eliminate the need to perform repeat searches on content that has already been searched. When investigating multiple items of information, the researched content does not easily become entrenched in human memory.

This study focuses on a famous method, the *Method of Loci* (also called "Mind Palace" or "Memory Journey"), as a method of allowing the retrieved contents to remain in memory for a more extended period of time. The *Method of Loci* is a method of retaining people and objects in one's mind by associating them. For example, consider the case that a person wants to memorize the ingredients for dinner for shopping. When using the Method of Loci, they first imagine their house in their mind. After that, they place the ingredients for appetizers in the entryway, the ones for the main dish in the living room, and the ones for dessert in their bedroom. Walk around that house and try to visualize what they need to buy in each order. In this way, they are not just memorizing words; people can also use their brain area for grasping space, making things easier to memorize and recall [7,9]. The aim, therefore, is to create an environment in which users can freely place search result Web pages in the VR space and organize them by freely moving them around. Therefore, by linking the search results in the VR space to places and organizing them in this way, there are expectations that the Method of Loci can be used to remember the results more effectively and reduce the number of searches during VR work.

The proposed method uses a Web browser that can search in the VR space, and make bookmark-like saves in the VR space. Figure 1 shows the actual screenshot of our system named the "Special bookmark"; a system that allows users to freely arrange browsers on the space and organize search results. The following VR rooms were created in order to verify what kind of space promotes memory retention based on the Method of Loci (see Fig. 2):

- **Sequential** Allainment room is a space that is just ordered like traditional bookmarks,
- **White** room is the user can freely allocate a browser in a spatial sense, but the direction in which the user is facing is unclear,
- **Four-colered** wall room is that the user can freely arrange the browser in a spatial sense, with painted walls on all four sides, and
- **Realistic** room with furniture in which a variety of objects are placed, as in a real room.

We conducted an experiment in which participants were asked actually to perform a retrieval task in each room. It makes it possible to verify what factors aid in memory retention and the effectiveness of this method.

2 Related Work

In this study, we proposed a method enabling better memory retention of search results for a more practical method of searching in VR environments. Therefore,

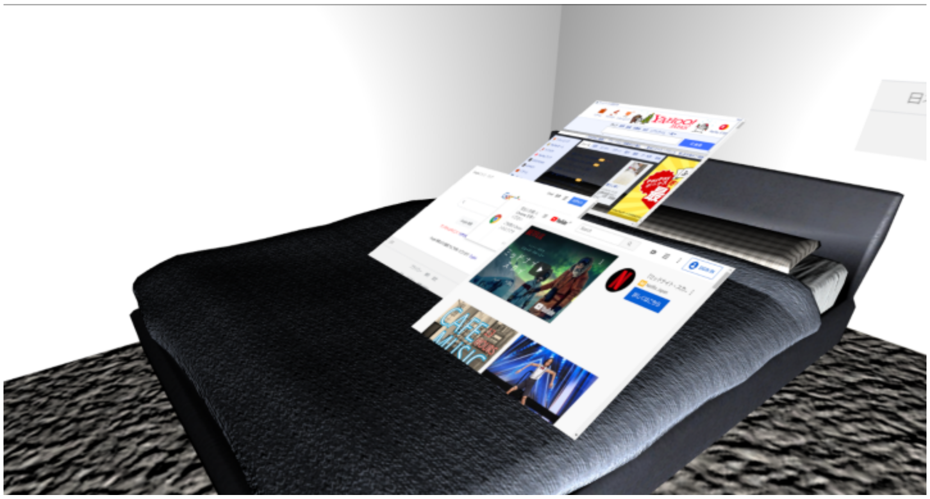

Fig. 1. A sample of a VR space where search result windows can be freely positioned. A browser window can be placed anywhere in the room, at any angle, and scaled down to any size.

this study is positioned in terms of an introduction to related research on Web browsing support in VR and the retention of accessed information in memory.

2.1 Web Browsing Support in VR

Web browsing support exists as a measure to counteract the difficulties presented when searching in a VR space. Among these difficulties, most studies have looked at methods of reducing the effort required to input text in VR. Speicher *et al.* [11] performed a comparative survey on six input methods. The results of the investigation revealed that the input performance of the method of crucial selection by pointing using VR controller ray casting is the optimal method.

Boletsis *et al.* [1] proposed a method in which text could be input by using a controller as a drumstick and mapping the motion of a drum beating to the key input. In this study, we aim to assist in accessing information in the VR space at a different level from the comfort of text input and browsing. These are interface improvements within the VR space so they can be used together without modification.

2.2 Retention of Information in Memory

Many studies have looked at methods of retaining information in memory. In studies by Bui *et al.*, [3] and Einstein *et al.* [5], it was noted that powers of memory are improved by notetaking. Gordon *et al.* [2] elucidated the possibility of strengthening memory related to one's own concepts or episodes.

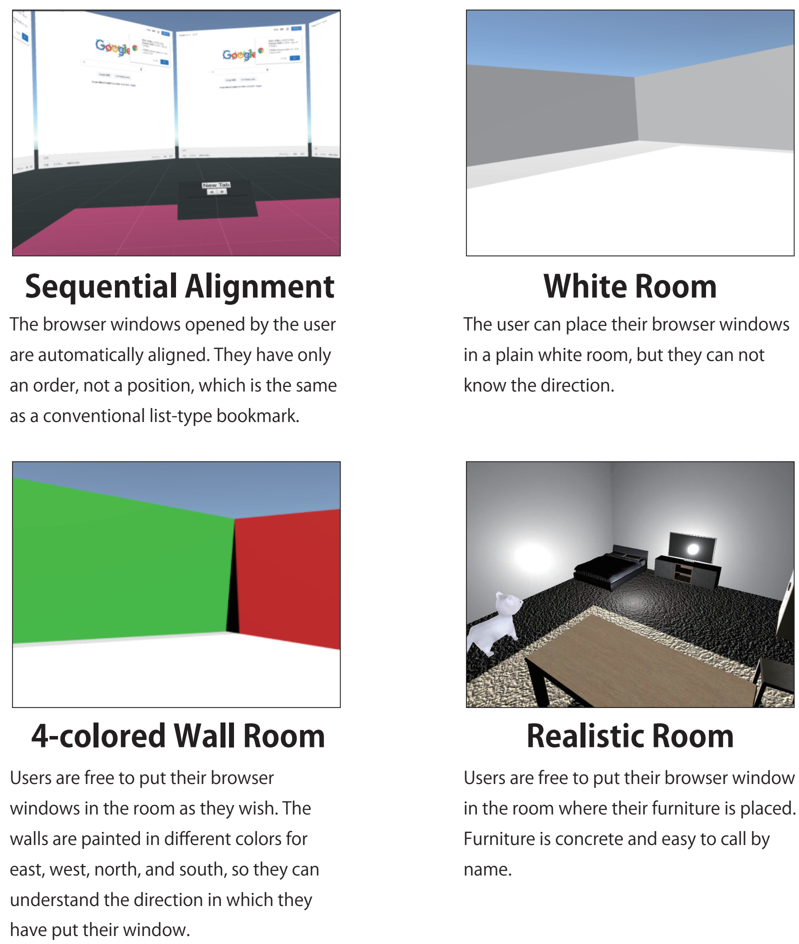

Fig. 2. Four different interior rooms. Each has a different level of abstraction. Users can put their search results windows in these rooms and organize them.

There have also been studies linking VR space and memory. Krokos *et al.* [10] asked participants to perform memory-related tasks in a visually immersive VR space, and verified that memory methods based on the Method of Loci could be effective in the VR space. Through this experiment, it was noted that both vestibular perception and cerebral reception help to retain things in memory. In this study, the Method of Loci is applied more specifically in the VR space to research on a Web page to determine what kind of space is adequate.

On the other hand, Hine *et al.* [8] noted that in experiments using memory with VR, this has a different impact on memory than in reality. In other words, a gap was noted regarding the ease of retaining memory, based on active and passive views. Elsewhere, Unsworth *et al.* [13] studied the influence of visual fidelity and active navigation provided in a virtual environment. This study also targets retrieval during VR games and works as a future application of this technology. When promoting this research in the future, it will be necessary to fully consider the memories and impressions that are unique to the VR space.

In a study strongly related to ours, Yang *et al.* examine the effectiveness of memory palace methods in general tasks that can be placed within a VR space [14]. Unlike their study, our research is a more localized, Web search-focused analysis. For this reason, we compared four different rooms rather than a large-scale comparison of effects.

3 "Spacial Bookmark" Approach

This section describes the method proposed in this study. In this study, we propose a method of memory retention based on the Method of Loci. Memory retention is achieved by placing things to remember in space, and based on the Method of Loci, the browser can be placed in the space freely reproduced in VR and saved like a bookmark. We named it the "Spacial Bookmark" approach.

The search results can then be organized on the place in a VR space. At this time, if the space in which the browser is placed in a white space without walls or ceilings, it will be unclear where it has been placed, given that it will not be possible to ascertain the eastern, western, northern, and southern directions. Therefore, the browser was placed in a room with four colored walls. However, even with color within the space, it was very abstract and difficult to ascertain the location. Therefore, the hypothesis was postulated that placing furniture and the like within the space would create a location that could more easily be expressed in words. To verify this hypothesis, we created three spaces based on the proposed method and one space that reproduced the conventional bookmarks within the VR space. Furthermore, when performing searches using these spaces, we added a memory function to enable an analysis of the search behavior of the users.

3.1 Overview of the Spatial Bookmark

In this study, we could organize the space by placing a screenshot of a Web page within the space. Whereas bookmarks on a typical computer are represented as a list or a tree divided into folders, bookmarks here are stored as coordinates within the space. The advantage of handling these kinds of bookmarks spatially in this way is that, based on the Method of Loci, it would be easier for the search results to be retained in memory, and it would be possible to reduce the effort required for repeat searches.

The Method of Loci is the method of memorization passed down since Ancient Roman times, and made famous by being summarized in the book "The Art of Memory" in 1966 by Yates [15]. This method is also commonly referred to as the memory palace method, the memory palace, or the journey method. In this method, when memorizing items, a person imagine an arbitrary place, and link the item they want to remember by placing the item in that place. At this time, the place they imagine can be an actual place like their home, an imaginary place, or even one of their body parts. It is thought that, as their memorize a place and the item to remember as a pair in this way, there are more cues when recalling, and this makes it easier to recall things.

3.2 Creating Browser Placable in Space

We generated multiple browser windows within the space, and created an environment in which they could be placed freely. The user is able to move freely within the environment and use the VR tracking device to generate a single tabbed browser window at any location. The generated browser can then be left at that location. In this way, it would appear as though the screenshot of the website seen at that location is placed there as is, and after touching the browser again, it would be possible to browse using that browser again.

The browser itself would have the same capabilities as conventional browsers, but there would be certain restrictions for using multiple browsers within the VR space. First, the "Back" button is allocated to one button on the controller, and all other navigation functions (*i.e.*, Forward, Update, etc.) are excluded. The concept is such that the user should access pages with individual information from the search results page when actually searching, return to the search result page if there is no information to be retained, and if there is information to be retained, place the entire window in the VR space and start a new window. The Close button is excluded for the same reason. This is because we want the user to overwrite and reuse windows other than those left as bookmarks within the VR space. Further, as, on this occasion, the information search is being carried out as the main task, we have yet to make it impossible to enter URLs directly. Finally, when a link is clicked, a new tab is opened, so the function to open a new window has been excluded. In this experiment, all browsers operate on a single tab. This is because multiple windows are placed within the VR space instead of opening multiple tabs within a single window.

When operating the browser on an actual VR device, the user wears VR goggles by changing the direction of his/her face up, down, left, or right, and is able to walk around within the space to the extent allowed by the cable. The browser operations are mainly operated with VR controls performed with both hands. In addition to its position detection ability, in terms of the direction the controller is facing, the controller has three physical buttons enabled on the controller: a trigger that can be pulled with the index finger, a side button that detects the user's grip, and a touchpad button that can be operated using the thumb. When the trigger is pressed, this has the role of the left click within the browser. This is also used when generating a new window or making active a window that has already been generated. If the user presses the side button, the user can grasp the browser window. The user can move the window in the grasped state, and by releasing this grasp, place the window in the location of their choice. As the controller is held in both hands at this time, they can grasp the window with both hands, and stretch and shrink it, in order to expand or contract the size of the window. By using this function, they can enlarge the window state when searching within the browser window and reduce it to a small state when simply placed within the space. The touchpad in a thumb-press position was used as a physical button for detecting presses, rather than as a touchpad. If they press the touchpad while operating the browser, they can move one step back in the browser history.

3.3 Creating a VR Space to Spatial Bookmarks

Several spaces have been prepared to actually allocate windows for browsers where it is possible to place windows as bookmarks within the created space. The aim of this study is to determine the space that can best facilitate the memorization of retrieved content based on the Method of Loci. In the original book on the Method of Loci by Yates, the space in which the object to be remembered is placed can be anywhere, such as a museum or a palace. However, within the VR space, as there are restrictions on physical movements as well as mechanical restrictions, it is possible that the optimal space will change. For example, a space where the user walks along a long route and places a memory in each room would be difficult to reproduce with VR.

For this reason, in this study, we prepared the following three VR rooms in phases:

– Most abstract space where the user can not know the direction,
– Slightly less abstract space painted in four colors,
– Space in which the place of allocation is expressed specifically in words,

and were able to organize the searches and results within the respective spaces. We set the spaces to the same size to prevent any disparity between spaces.

Abstract Rooms We created two VR rooms in which users are able to simply search and move the search browser within the VR space. These are the most primitive spaces for organizing information. In these spaces, the test participant generated windows and searched in spaces that were nothing in particular and were able to allocate the windows they liked to their favorite places within the space.

The first abstract space is completely indistinguishable from front to back and left to right and is surrounded on all sides by pure white walls. The image of the actual space is shown in the upper right of Figure 2. It is possible to search within this space, and place the search browser in the desired location, but as the user does not know in which direction they are facing, the mutual placement of browsers is all relative. For this reason, even if they can remember something by saying "placed to the left on the previous page," they cannot say "placed in the western direction."

The second space is a room like the first space, but with the concept of direction added. An image of the actual room is shown in the bottom left of Figure 2. In this room, the four walls are color-coded in four colors; red, blue, yellow, and green. As a result, the browser is not simply relative, and also has meaning as an absolute position. In this space, the user can organize related pages together by considering the direction, such as "Let us place pages related to this topic in the direction of the red wall and pages related to different topics in the direction of the blue wall," which allows users to organize the information based on direction.

Specific Room In addition to the two abstract spaces, a specific space based on the motif of an actual room was prepared. An image of the actual space is shown in the bottom right of Figure 2. In this space, we can see a simple arrangement of furniture, with a bookshelf, bed, desk, and chair. In this space, the coordinates, in addition to having a relative position, have an absolute position as the azimuth, and also have fine-grained absolute positions, such as "placed near this furniture."

The types of furniture placed in this space are limited to furniture where the name easily comes to mind for whoever is looking at it. Other objects with more difficult-to-recall names were not placed in said space. This is because the name of the furniture is thought to become a hint for people to more easily recall where they placed things later.

In this space, it is possible to organize information in terms of where things were placed, by linking to objects, in the form of "This perspective on this topic is placed on the top-left of the TV" or "a perspective on a separate topic is placed on the bed."

Space Only Has Order The bookmarks in conventional browsers only have order and a hierarchical structure, and do not possess spatial coordinates. For the purpose of comparative experiments, we created a space that reproduced bookmarks with only order in the VR space. An image of the actual space is shown in the top left of Figure 2.

In this space, by pressing the Favorites button in a place where the user wants to leave a bookmark, a new window opens next to the user. The user is able to continue searching by using this window. In this space, the user is not able to freely move the browser. For this reason, it can only remember in terms of order within a series, in that a certain page is “bookmarked before that page” or “was bookmarked first.”

3.4 Collecting Behavior Logs for Analysis

labelss:Log Operational logs remain for each search browser in the space. The time, movement coordinates, and investigated URLs are recorded in the log. Elements recorded as time include the time that the Web browser was generated and the time it was in the active state. When a browser is moved for the purpose of the organization, it records from where it was moved from and to and when. Finally, the URL actually accessed is recorded as the behavior within the browser.

Additionally, the screen actually seen by the user in the VR space can be captured as video. By combining these three logs and screen captures, the user can learn the browser’s behavior within the space, such as what kind of web pages are opened and how they move.

4 Evaluation Experiment

We implemented the proposed method and evaluated each space through subject experiments to confirm in which space the search contents are most easily remembered.

4.1 Implementation

We implemented the system using Unity to enable the browser to be placed within the proposed VR space. The implementation used OpenVR and SteamVR. In this experiment, we used HTC Vive and HTC Vive Cosmos, respectively, for the experimental head mount displays. When implemented, room-scale tracking was enabled, and this allowed the user to use the controller to actually physically walk and place the browser within the room without moving. For the browser implementation, we used an *Embedded Browser*, generally sold as a Unity asset. With the Embedded Browser, the Chromium browser for Desktop use can be used within the VR space. For the experiment, we restricted some functions; the user cannot open multiple tabs in a single window, and cannot open menus.

The four spaces, including comparative methods, were reproduced in the respective VR spaces, and the following were implemented:

- **White** Room is a space where the user can not know what direction they are facing,
- **4-colored** wall room is a space separated into Four colors
- **Realistic** room with furniture is a space in which the location can be easily expressed in words, and
- **Sequential** alignment is a space in which the browser is automatically placed in the horizontal direction.

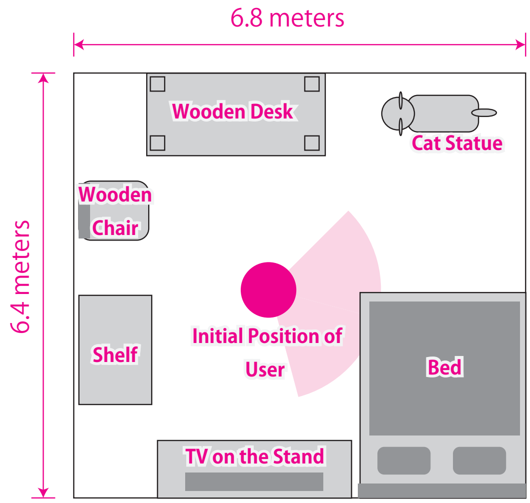

Fig. 3. Layout view of the Realistic room. Objects that are easy to describe in words are arranged around the user's initial position.

The first **White** room is a space that is six meters long and two meters high. It is square and surrounded by white walls, so the user cannot know what direction they are facing. The **4 wall color** space was also 6 meters long and 2 meters high, in the same way. The structure of the space itself is the same as in **White**, but the walls surrounding the four sides are painted red, blue, yellow, and green, respectively. The **s**pace with furniture has a variety of furniture placed within a room that is six meters long. As shown in Figure 3, objects such as a TV, bed, shelf, desk, and cat are placed inside the room.

The experiment with the participant was carried out in a specialist lab with a dedicated 6.4 x 8.6 m VR experiment space. An image of the experiment is shown in Figure 4. In terms of the setup for the actual experiment, HTC Vive tracking sensors were placed three meters apart, and participants were free to walk between them in order to search the Web and organize the results.

4.2 Experiment Settings and Procedure

We evaluated the extent to which information could be retained over the long term when linked to information when searching in the VR space. For this purpose, we requested that the six participants perform a search task in VR, collect logs, and then go back to them one week later to check the extent of their recall regarding the search content. The time required for the search task was two hours per person.

The search task imposed on the test participants was to collect and organize a wide range of information and, finally, provide a conclusion. The test participants

Fig. 4. Experiments were conducted in a room-scale VR environment of 6.8 x 6.4 meters using HTC VIVE.

finally performed decision-making based on the collected information and created one ranking. Specifically, we first created a list of candidate Ferris wheels, such as “the most suitable Ferris wheel for a date in Japan,” and then examined the location and facilities of each the candidate Ferris wheels, and finally sorted them in order of their suitability.

This kind of search task mimics typical search behavior in everyday life. For example, let us suppose we buy a new smartphone. At that time, we always choose which smartphone is best based on certain information we gather, such as image quality and performance. In this way, natural search behavior is gathering information when searching, examining, and selecting the information we want.

The actual experimental procedure is as follows: First, the test participant answers a questionnaire in advance regarding their method of performing searches and whether he/she has used VR. Next, the test participant operates the proposed system for 30 minutes in order to become familiar with the VR operations, and freely perform Web browsing. Then, after a 30-minute break, he/she performs search tasks in the four spaces over the course of one hour. After completing the search tasks, the test participants ranked their own search results based on what they searched for and selected the top three results. Then, one week later, they answered regarding what extent they remembered the top three rankings of the search results.

4.3 Experimental Task

In terms of a search task in which participants examine a large quantity of information, discard certain information, and make decisions, a search task is set in which they choose their top three, respectively from

- **Ferris wheel**: Finding the best Ferris wheel considered to be appropriate for dating in Japan, and

Table 1. Combination of a given experimental task and a VR room for each participant. Considering order effects, each participant experiences the realistic room and one other room.

Participant ID	Fisrt Task	Second Task	First Room	Second Room
1	Ferrs Wheel	Migration	Realistic	4-colored
2	Ferrs Wheel	Migration	Realistic	White
3	Ferrs Wheel	Migration	Realistic	Sequential
4	Ferrs Wheel	Migration	4-colored	Realistic
5	Ferrs Wheel	Migration	White	Realistic
6	Ferrs Wheel	Migration	Sequential	Realistic
7	Migration	Ferrs Wheel	Realistic	4-colored
8	Migration	Ferrs Wheel	Realistic	White
9	Migration	Ferrs Wheel	Realistic	Sequential
10	Migration	Ferrs Wheel	4-colored	Realistic
11	Migration	Ferrs Wheel	White	Realistic
12	Migration	Ferrs Wheel	Sequential	Realistic

- **Migration prefecture**: Finding a prefecture in Kyushu (an area in Japan) suitable for working and raising children if you move there when you are 30 years old.

It is not possible to create a ranking for these two tasks unless multiple searches are performed. In the Ferris wheel task, participants were given an abstract search goal of finding the "most appropriate one for a date" and were required to go to multiple Ferris wheel-related Web sites in turn to find information on what they themselves considered appropriate for a date. In the migration point task, based on the search goal of finding a place "appropriate for working and raising children," as part of this task, participants were asked to examine the suitability of each of the Kyushu prefectures from various perspectives in terms of working and raising children. By comparing and examining information, they finally create a ranking of the top three. The test participants were prohibited from creating rankings by browsing only summary or ranking sites. This was to ensure that they made their own decisions.

4.4 Experimental Participants

A combination of the four spaces was created, taking the order effect into consideration. Given that the superiority or inferiority of each method could not be discussed without a minimum of twelve participants, we were only able to verify the combinations represented in Table 1. When performing these tasks, an equal number of test participants performed the proposed method first as the number performing it later. Additionally, as there were two types of tasks and four types of spaces, the 12 participants performed the tasks in an interchangeable order, that is to say, before and after the space and before and after the task.

4.5 Questionnaire on the Day and One Week Later

participants were asked to respond to the top three rankings in the search task they performed for that day's evaluation. In the evaluation, after one week had passed, the test participants responded in regard to how much they recalled.

In addition to the ranking items, they answered in regard to whether they could remember what information was placed where. They were also requested to respond with how they were able to recall the information. In this way, it is possible to judge the recall and reaffirmation. To confirm recall, they were asked whether they recalled the rankings themselves. To confirm reaffirmation, they were asked whether they remembered what was placed where.

4.6 Results of the Experiment

In this experiment, to measure to what extent it was entrenched in memory, it was judged whether the rankings in the search task on the day in question and one week later matched. In the experiment conducted on this occasion, the degree of memory retention of the participants could not be assessed by ranking the retrieval tasks, and there were differences in the quality of how much information they could recall. In regard to the i-th ranking element created in task t by test participant u, the matching $co(u, t, i)$ between the answer a_{morrow} immediately after the task and the answer one week later of a_{later} is defined as

$$\begin{cases} 1: & a_{\mathrm{morrow}} = a_{later}, \\ 0: & \text{otherwise.} \end{cases} \tag{1}$$

At this time, the extent to which the search results of task t are entrenched in the memory of test participant u is expressed as the mean matching level:

$$f_{task}(t, u) = \sum_{i=1}^{\mathrm{ranknum}} \frac{co(u, t, i)}{\mathrm{ranknum}}. \tag{2}$$

Here, this is set as ranknum = 3. If this value is summarized for each space and the set of tasks carried out in this space r is expressed as $T(r)$, this becomes:

$$\sum_{t \in T(r)} \frac{f_{task}(t, u_t)}{|T(r)|}. \tag{3}$$

At this time, the executor of the tasks carried out in this room is expressed as u_t.

As shown in Table 2, a space with **Realistic** room is able to support memory retention better than a **White** space, but not as good as a room with **4-colored** walls.

The number of people who remembered the place in which the information was placed and the number of people who remember the information itself for each space is shown in Table 3. The space in which the highest percentage

Table 2. Memory retention rate after one week for each VR room. Because participants examined several candidates and answered the top three, it shows the correct answer rate for each of their top three answers.

Room Type	1st	2nd	3rd	Average
Realistic	0.91	0.83	0.91	0.89
4-colored	1.00	1.00	0.75	0.91
White	0.50	0.50	0.75	0.58
Sequential	0.75	0.75	0.75	0.75

Table 3. Details of what participants remembered after one week from the survey evaluation

Room Type	Location where they put browser		What they searched for	
	Remembered	Forgotten	Remembered	Forgatten
Realistic	11	1	11	1
4-colored	2	2	2	2
White	2	2	1	3
Sequential	-	-	1	3

of participants who remembered all the information was found was the space **Realistic** room with furniture, Furthermore, the **Realistic** room also had the highest percentage of people who remembered what kind of information was investigated.

5 Discussion

In this section, we focus on the four stages based on the experiment results, of support for the retention of information in each space, VR familiarity, sequential effects, and memory, and discuss whether the proposed method supports memory retention. In general, there was a high degree of memorization of search results one week later for all rooms. In regard to the memory task in the **Realistic** room, although there was no particular trend toward higher memory retention when taking the average of all test participants, there were differences in how much detail of the retrieved results could be remembered.

First, we shall discuss the results of each method. In addition to having the second highest retention rate among all spaces, the space with **Realistic** room had the highest percentage of participants who remembered the location in which the information had been placed. When comparing **Realistic** room against the existing method, the test participants moved more during the search. It is considered possible, therefore, that the physical movement of the participant's body, as well as the difference in the space, may have impacted memory retention.

The following should be noted: Some test participants who experimented with this combination used a unique memorization method of linking the information and words together. Specifically, in the **Realistic** room, they used word association to memorize the information and the furniture placement locations. This is kind of a pun; such as "Kagoshima (the name of a prefecture) is in a cage." When using this method of memorization, whereas all the information researched in the **Realistic** room was remembered, some of the information in the **Sequential** a space was forgotten. Having the user associate the VR space with things that can be easily expressed using words is thought to enable effective memory retention when the user associates the VR space with existing memory methods such as word association.

The room with **4-colored** wall had the highest memory retention among all the spaces, but when asked whether they could remember the place where the information was placed and what information was searched, half of the respondents answered that they could not. Compared to the **Realistic** room, many made mistakes when recalling the placement location. Specifically, the test participants remembered where they had placed the information on the Ferris wheel that was supposed to be in second place, and where they had placed the information on the Ferris wheel that was in third place, but in reverse order.

Compared to all other spaces, the level of memory retention was lowest in the **White** space. This may be because, compared to the **Realistic** room and the **4-colored** wall room, it was hard to summarize what had been placed and where. Specifically, one test participant placed a summary of all Ferris wheels to his/her own right in the **White** space, but answered that he/she had put the information for each Ferris wheel on his/her left side. They made a mistake with the placement of information on the left and right, and this content was not remembered in detail.

In the **Sequential** alignment space, in the majority of cases, the test participant did not remember the search results. This is thought to be because actions could not be summarized without moving the browser, as in the **Realistic** room. Specifically, if we focus on one test participant, in the migration point task, they researched locations in terms of the three items of ease of working, the convenience of transportation, and positive effect on child-rearing. However, one week later, they could not remember what kind of information they had researched. On the other hand, if we focus on memory retention, the level of memory retention is not as high as the **White** space. This may have been because the act of active summarization in the **White** space was more burdensome from a work perspective, they focused more on the operation, and the result of this was that it was easier to focus on the information in the less intensive **Sequential** alignment, making it easier to retain the information.

In terms of VR familiarity, all test participants responded that it was easier to perform the later task than the first task because they were familiar with the operation. Given the effect of VR familiarity, it is possible that the later results may be more easily retained in memory due to the effects of familiarity. The majority of test participants had a higher level of memory retention for the search task performed first than for the search task performed later. Some participants remembered information in more detail in the first search task than in the later search task. As one of the test participants did not remember the results of either task, if we consider that this participant should be excluded as an outlier, the later search task did not produce abnormally high results. Based on this, we can consider that the impact of VR familiarity is low.

It is also possible that the order effect may have impacted memory retention. As many of the test participants were experiencing VR for the first time, the search results for the first task carried out may have remained particularly strong in memory. In this experiment, the memory retention of the latter space of test participants who experienced the **Realistic** room first was relatively low. It is thought that the search task conducted first had a greater freshness, and this may have made a significant difference in the rankings. In addition, the test participants who performed the **Realistic** room task later had greater memory retention from the later search task than the earlier search task. For this reason, it is considered that, though the order effect has an impact on the results, even when considering the order effect, the **Realistic** room is thought to be able to support memory retention.

The aim of this study is to support memory retention. For this purpose, we confirmed recall and reaffirmation in four stages. Recall was confirmed based on whether the test participants could remember the ranking. However, in this experiment, there was no significant difference in memory accuracy among the test participants in any of the spaces. This is thought to possibly be due to the search task being simple on this occasion. As the top three items were the top three items in the simple search task, there was no significant difference. This was also more memorable due to the VR experience, which is something that is not usually experienced. For this reason, it was not possible to determine whether improved recall occurred with the present method in the **Realistic** room. For reaffirmation, on the other hand, differences appeared between the **Realistic** room and the other spaces in terms of remembering the places information was placed and what information was searched. The places information was placed were remembered more in the **Realistic** room than the other spaces, and the searched information was remembered in more detail. More reaffirmation is thought to have occurred in the **Realistic** room than in the other rooms.

Based on this, it may be suggested that, although there was no significant difference in the number of search results that could be recalled when considering the possibility of memory support based on the Method of Loci, it may have had an effect on the amount of content remembered.

6 Conclusion

This study proposed a *Method of Loci*-based method named “spatial bookmark” for facilitating the recall of search results. It allows placing the search browser that performs the search in the VR space by itself. Four rooms were created within the VR space: a realistic room that could be easily expressed in words, a space color-coded with four colors, a pure white space, and the Sequential space like traditional bookmarks. An experiment was conducted in which participants collected information from the Web and made a ranking. One week after the experiment, a survey was conducted regarding how much of the search content was remembered, using a questionnaire. Based on the experiment results, it was impossible to accurately measure the same day and next day evaluation of the rankings due to the simplicity of the search task. However, the quality of memory retention differed between the spaces. Information was recalled the most when searching in a room with **4-colored** walls. The content of the information researched in the **Realistic** room was remembered in detail, and the location of placement was also remembered accurately. Finally, our study showed the possibility of making users remember their searches by organizing the search results in a non-abstract room.

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