Memorization and Information-Retrieval Behaviors

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Abstract. What is the relationship between memorization of information and the behavior used to retrieve that information? Searching for photos stored on a media is a common activity. Chances are that it is easier to find some types of photos than others. To determine the reason for this, we conducted a user study to clarify the mechanisms people use to retrieve information. We found that the operational patterns differed with the degree of memorization and the types of target photos. In particular, we found that the overall relative positions of target contents and/or the order of the arrangement affect memorization. The difference in operational patterns can be interpreted as a difference in retrieval strategies. These findings should contribute to the field of computer-human interactions, enabling the mechanisms used to retrieve information to be better understood. This understanding should lead to interfaces that can dynamically and appropriately assess user intentions and situations.

Keywords: Information-retrieval, scrolling, memorization, operation patterns.

1 Introduction

Due to the rapid progress in information technologies, we live in a society where we can enjoy a rich variety of digital information. However, the complexity of the interfaces between digital information and potential users has increased, and accessibility to the information they require has been reduced. Even though a great deal of research on user interfaces has been done, and many excellent results have thus far been obtained, there have not been that many studies on the mechanisms people use to retrieve information. If we could understand them more clearly, novel and instinctive user interfaces based on these mechanisms could be attained.

In our user study, we focused on scrolling because this is one of the basic methods for retrieving digital information, and investigated how the degree of human memorization and the features of the targeted information affect the scrolling operation. For example, someone searching for a favorite photo in a folder may be able to find it immediately without straying because he/she remembers the folder's contents and the photo's whereabouts well. In contrast, someone searching for a friend's favorite photo in an unfamiliar folder will likely take longer to find it and may stray in the information space. This illustrates that the scrolling pattern used may be affected by the target information. We asked the participants to retrieve photos by scrolling, and we measured the time it took to find the target photo, recorded the identification numbers of the photos viewed (the "scrolling position") for every time unit, and derived the velocity from the changes in position. We also asked them to complete a questionnaire that enabled us to estimate how well they remembered the target photos, not only their features but also their position in the arrangement.

The rest of this paper is organized as follows. After briefly introducing related work, we describe the motivating hypothesis in Section 3. Then we describe the user study we conducted in Section 4, and present some of the results in Section 5. In Section 6 we discuss the results, and finally describe our conclusion.

2 Related Work

Several cognitive psychological studies have investigated how people use Web browsers and their information-retrieval behaviors [4,5,6,7,15,16]. These have shown that a user's retrieval behavior is driven in part by the way information is presented. That is, the user interface design affects the retrieval behavior. The results of these studies have been used to develop tools for designing and evaluating Web pages, and techniques to improve browsing or searching content-rich information [14,17].

People are generally good at retrieving things stored spatially. Several groups have conducted studies aimed at organizing digital data spatially like we do in the physical world [1]. One approach has been to reproduce the arrangement of objects on a physical desk on the computer. Stacks of files are arranged at spatially different positions on a desktop-like GUI as groups of information.

An investigation of the relationship between scrolling distance and the required precision of scrolling [8] revealed that Fitts' Law models the scrolling behaviors well, though it is usually used to evaluate the performance of pointing devices. This investigation of how conventional scrolling techniques are actually used resulted in a paradigm that can be used for designing new retrieval techniques.

Various methods have been proposed for the scrolling operation. Igarashi et al. proposed a scrolling technique for browsing a large amount of content using a zoom function [9]. The pseudo speed of scrolling is kept constant by automatically zooming in and out in accordance with the speed of operation. This technique utilizes the scrolling speed to dynamically change the content presentation. However, it does not take the relationship between the types of content and scrolling operation into consideration.

Appert et al. proposed a technique for automatically adjusting the zoom level in accordance with the user's operation, not the operation speed. Their OrthoZoom Scroller [2] controls the zoom level by moving the pointer in the direction perpendicular to the scrolling direction. As the pointer approaches the scrollbar, the contents are presented with lower precision, and as the pointer moves away from the scroll bar, the contents are presented in higher precision.

Kumar et al. proposed using eye gaze to control scrolling [12]. They focused on the finding that scrolling is strongly coupled with a user's ability to catch information using his/her eyes. For example, the placement of a document being read on a screen can be maintained even when the page up or page down key is pressed by detecting the eye-gaze point and using it to limit the scrolling edge.

For supporting user operations, some studies have suggested using the users' operation tendencies to deduce their intentions. Asano et al. used the direction and peak speed of pointer movement to deduce the target and automatically scroll to it [3]. Kobayashi et al. proposed a technique for operating a cascaded menu [11]. The direction of pointer movement is mapped to the direction of the cascaded-menu items, and the user does not have to actually point to an item to open it. Ishak et al. described a scrolling method that depends on the content characteristics [10]. The speed of scrolling and zooming automatically changes in accordance with the context of the content. For example, if a document with two columns is being read, the scrolling operation is supported by a function for automatically jumping from the bottom of the left column to the top of the right column.

Improving the scrollbar has been another topic of interest regarding scrolling. In one study, a rubber band metaphor was used to control the scroll speed [13]. The speed changed with the distance between the pointer and the scrollbar slider. When the user drags the slider, the speed of scrolling is the same as that of the slider. When the user drags somewhere else in the scrollbar area, the speed of scrolling is higher the greater the distance between the mouse pointer and the slider. This enables more precise pointing to the desired contents because the closer the target content comes to the screen, the lower the scrolling speed.

Most previous studies focused on the functions or design of the user interface itself, not on the effect the target contents has on using the interface. In this study, we focused on how the contents affect a person's use of an interface. We attempted to clarify the mechanisms people use to retrieve information and explored the possibility of using them as a basis for novel computer-human interaction techniques.

3 Hypothesis

In this study, we investigated the relationship between memory and retrieval behavior by conducting a user study in which users retrieved target photos using scrolling. The scrolling speed was controlled by the user and was not constant during the retrieval process. The identification numbers on the photos scrolled through were recorded, and the number of photos scrolled through per time unit was used as a measure of the scrolling speed. The speed varied with the operation pattern, for example, how long keys were pressed or the speed at which the slider was moved. We hypothesized that the shape of the scrolling pattern (Fig. 1) depends on the user's memorization of the target contents and that the patterns can be categorized on the basis of their shapes.

The time it takes to find a target photo in a folder and the psychological load are affected by how well the searcher remembers the contents of the folder and their order. This means that the scrolling patterns for well-memorized photos should differ from those for poorly memorized ones. The memorization can be affected by both the features of the contents, that is, the contents themselves and their overall relative positions. Though a computer cannot directly calculate the degree of a person's memorization, there is a relationship between the degree of memorization and the features of the contents that a computer can calculate. There are characteristic differences between photos that tend to be well memorized and those that are not. A series of photos with the same theme taken on nearly the same date or at the same time can usually be easily distinguished in a folder of photos. Photos with strong features such as tone or composition can also usually be easily distinguished. Thus, we categorized the target photos into three types before conducting the user experiment: “series,” “impressive,” and “featureless.” We investigated the relationship between photo type and ease of memorization and between photo type and operation pattern.

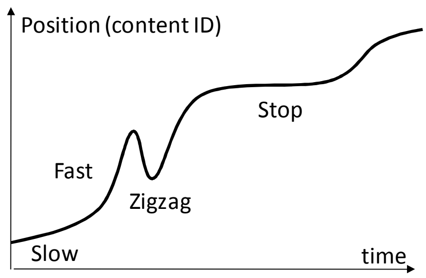


Fig. 1. Example plot of scroll track.

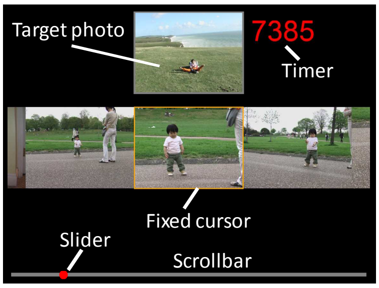
4 User Study

The participants were asked to find a target photo from among 200 photos using two types of operation.

- Operation 1: Use only left and right arrow keys on keyboard to scroll.
- Operation 2: Use only mouse movements to drag scrollbar slider.

Eight people (two women and six men, 25 to 42 years old) familiar with computer operation participated. Photo browsing software was run on a desktop PC with a 24-inch display (Fig. 2 (a)). The photos were presented in one dimension horizontally across the middle line of the display. A fixed cursor was presented at the center of the display, and three photos were shown at once. The target photo was shown in the upper-center area. The participants scrolled through the photos by dragging the scrollbar slider using the mouse in operation 2. They could also scroll by pressing the left and right arrow keys on the keyboard (in operation 1), and the slider moved in accordance with how the keys were operated. There were five steps in the experimental process.

1. We gave the participants (one at time) 3 min to memorize the features of a total of 200 photos and their order.
2. The participant pressed the Enter key to start searching. The target photo was displayed, and the timer started. The participant scrolled by pressing keys (in operation 1) or dragging the scrollbar slider (in operation 2) to find the target.
3. The participant pressed the Enter key again when the target photo was apparently found in the fixed cursor. If the photo was the target one, the task was accomplished and the timer stopped. If not, a beep was sounded, and he/she resumed searching.
4. After the participant found the target photo, he/she answered three questions on a questionnaire.
5. Each participant repeated steps (1) to (4) for 12 photos, once using keyboard operation and once using mouse operation, i.e., 24 tasks in total.



(a) Photo browser.

Q1: Did you remember the photo itself?
1: Yes 2: No
Q2: Did you remember its position?
1: Yes (Accurately)
2: Yeah (Almost)
3: No, but remembered (Remembered during the operation)
4: No (Not at all)
Q3: Did you find it where you expected it to be?
1: Yes (exactly) 2: No (different)

(b) Inquiries.

Fig. 2. Photo browser and inquiries for experiment.

Each time the participants finished a task, they were asked to write their answers to three questions (Fig. 2 (b)). The first question ("Did you remember the photo itself?"; "yes" or "no") was used to investigate the effect remembering the photo itself had on the operation pattern. The second question ("Did you remember its position?"; "yes (accurately)," "yeah (mostly)," "no (but remembered during the operation)," or "no (not at all)") was used to investigate the effect remembering the photo's position had on the operation pattern. The difference between Q1 and Q2 was "position." Someone may remember the photo itself and the position as well. Others may remember the photo itself but not the position. The operation strategies may be different between these two. The third question ("Did you find it where you expected it to be?"; "yes (exactly)" or "no (different)") was used to confirm the accuracy of their memory. From the results of the last two questions, we defined a "memory score," which represented how memorable the photo was.

The same 24 of these photos were used as retrieval targets, and they were presented in the same order to all participants. The 24 photos were categorized into three types: "series," "impressive," and "featureless." The "series" type included photos that had been taken in close succession and had the same theme. The "impressive" type included photos that had strong, easily remembered features. They included photos that were striking in some way, such as photos with strong tones, an interesting composition, or a strange object. The "featureless" type included photos that were not in a particular series and had no strong features. For example, a photo between one series and another series could be of this type. In the experiment, we recorded the identification numbers of the photos located at the fixed cursor position during each time unit (100 ms). We then derived the velocity from the changes in position. The entire time it took to find the target photo was also measured.

5 Results

5.1 Classification of Scrolling Patterns

We gathered scrolling-pattern data, i.e., the ID numbers of the photos scrolled through (i.e., the scrolling position) and the derived velocity of scrolling for the eight participants for both the keyboard and mouse operations. Some of the patterns had a similar shape even though they were for different target photos or were for different participants. This indicates that the scrolling patterns can be classified using several typical patterns and their combinations. We found that we could use four typical patterns for each type of operation to classify all the patterns. All the gathered patterns can be one of the four patterns itself or the combination of them. As shown in figures 3 and 4, the patterns comprised two plots: position (ID) vs. time and velocity vs. time. The patterns in the figures are for actual data obtained from the user study.

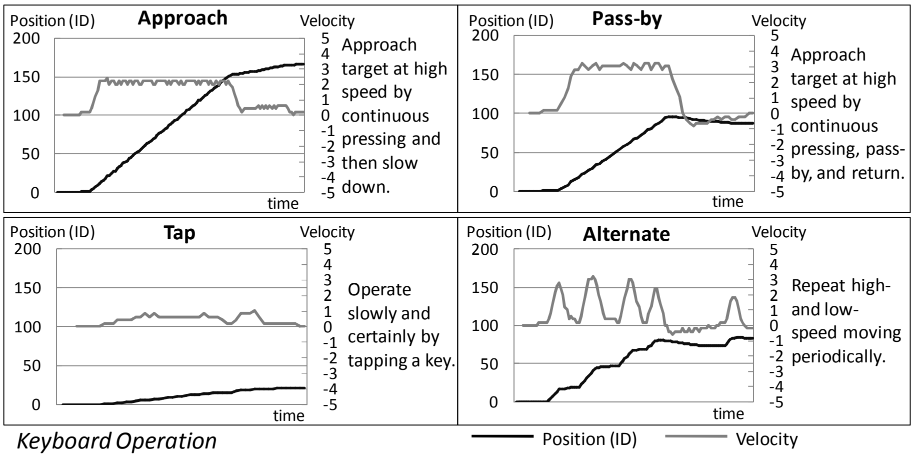


Fig. 3. Typical scrolling patterns for keyboard operation.

Scrolling Patterns for Keyboard Operation (Fig. 3)

"Approach": The user continued pressing (key down) an arrow key until the target photo appeared. He/she then stopped pressing and started to tap the key to scroll slowly until the target photo was reached. That is, he/she approached the target at high speed by continuously pressing a key and then slowed down. The slope of the position plot is initially steep, and then it becomes gentle near the target; the velocity plot forms a trapezoid.

"Pass-by": The user continued pressing an arrow key until the target photo had been passed. He/she then stopped pressing and started to tap the key for moving in the opposite direction to scroll slowly back to the target photo. That is, he/she approached the target at high speed, passed the target, stopped suddenly, and returned to the photo. The slope of the position plot is initially steep, and then it becomes gentle with opposite inclination; the velocity plot forms a trapezoid.

"Tap": The user scrolled by continuously tapping an arrow key. That is, he/she operated slowly and certainly by tapping a key. The position plot remains fairly steady, and the velocity plot has a very gentle slope.

***"Alternate"**:* The user alternated between continuously pressing an arrow key and tapping an arrow key. That is, he/she periodically repeated high- and low-speed moving. The position plot has steps, and the velocity plot has spikes at semi-regular intervals.

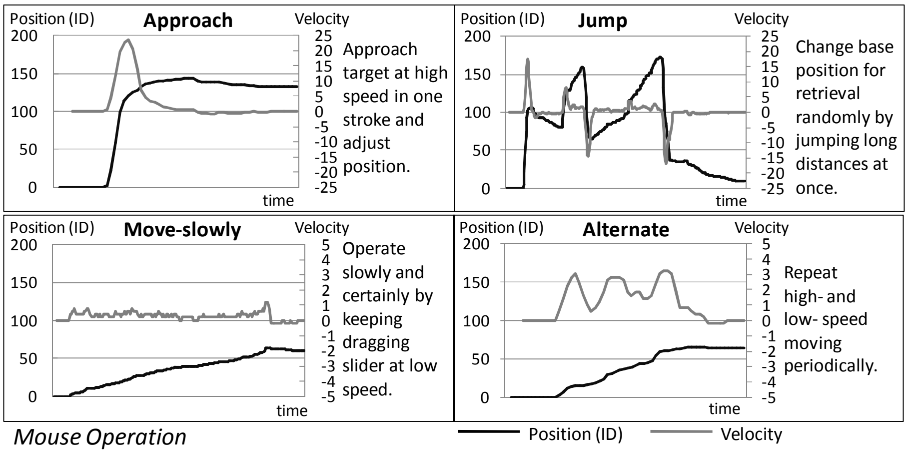


Fig. 4. Typical scrolling patterns for mouse operation.

Scrolling Patterns for Mouse Operation (Fig. 4)

"Approach": The user initially dragged the slider quickly over a long distance, scrolling through numerous photos until the neighborhood of the target photo was reached. He/she then slowly searched through the neighboring photos until reaching the target. That is, he/she approached the target at high speed in one stroke and then carefully adjusted the position. The position plot has a very steep, almost vertical, slope, and the velocity plot has one sharp peak near the beginning and then remains flat.

"Jump": The user alternated between suddenly and rapidly moving the slider over a long distance and moving it very slowly until the target was reached. That is, he/she randomly changed the base position for retrieval by jumping long distances at once. Both the position plot and the velocity plot have discrete sharp peaks. This is a characteristic pattern of mouse operation and is not found in keyboard operation.

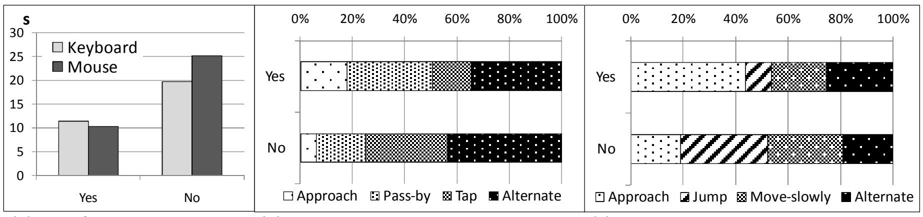
"Move-slowly": The user moved the slider slowly and continuously until reaching the target. That is, he/she operated slowly and certainly by dragging the slider. The average speed of scrolling was very low. The position plot remains fairly steady, and the velocity plot has a very gentle slope.

"Alternate": The user alternated between moving the slider over long and over short distances (or stopping). That is, he/she periodically repeated high- and low-speed moving. The position plot is stepped, and the velocity plot has spikes at semi-regular intervals.

We then defined representations for all the scrolling patterns. For example, if the scrolling pattern was simply "approach", (approach, pass-by, tap, alternate) was represented as (1,0,0,0). If the pattern included both "pass-by" and "tap," it was represented as (0,1,1,0). The former representation is interpreted as "approach 100%" (i.e., the rate of use was 100%); the latter is interpreted as "pass-by 50% and tap 50%" (i.e., the rates of use for both patterns was about 50%).

5.2 Degree of Memorization of Photo Itself and Operation Pattern

In the questionnaire (Fig. 2), we asked the participants whether they remembered the target photo itself. Using the answers to Q1 and the scrolling pattern representations, we identified the relationship between the degree of memorization of the photo itself and the operation pattern. As shown in Fig. 5 (a), finding unremembered photos took longer, and the difference in retrieval times is consistent with it being more difficult to find unremembered photos than to find remembered ones.



(a) Time for retrieving. (b) Keyboard operation. (c) Mouse operation.

Fig. 5. Time for retrieving (a) and details of operations (b), (c) for the answers to Q1, "Did you remember the photo itself?"

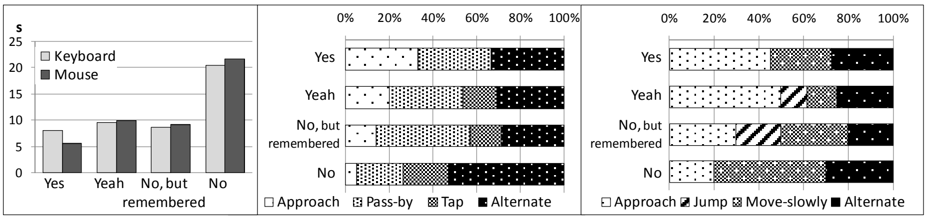
Answer to Q1 and Keyboard Operation: As shown in Fig. 5 (b), the participants who answered "yes" to Q1 for keyboard operation used the "approach" and "pass-by" scrolling patterns at a combined rate of about 50%. Those who answered "no" used them at a combined rate of about 25%. This is consistent with the idea that a user who remembers the target photo will tend to scroll quickly because he/she can catch a rough impression of it even when the photos are scrolled rapidly. Additionally, a user who remembers the position of the photo can move toward it without straying. A user who does not remember the photo has no clues for finding it and will thus tend to scroll through the photos more slowly, with more dependence on visual feedback.

Answer to Q1 and Mouse Operation: As shown in Fig. 5 (c), the participants who answered "yes" to Q1 for mouse operation used the "approach" scrolling pattern at a rate of about 45%, while those who answered "no" used the "jump" pattern at a rate of about 35%. That is, someone who remembers the target photo can approach the target with one long movement. Someone who does not basically scrolls slowly, and, if he/she cannot find the target, he/she changes the base retrieval position by scrolling a long distance in one stroke. That is, they jump to a new position and start searching again slowly.

5.3 Degree of Memorization of Photo's Position and Operation Patterns

We have seen that differences in remembering the target photo caused significant differences in operation patterns and retrieval times. Next, we focus on the effect of remembering the target photo's position rather than the photo itself because this information could prove useful in finding the photo. The scrolling patterns for "remembering the photo but not the position" should differ from those for "remembering the photo and the position as well." We thus analyzed the representations for Q2 ("Did you remember its position?") for those participants who answered "yes" to Q1.

Fig. 6 (a) shows the retrieval time for each pattern. The participants who did not remember the position of the target photo (Q2: “no”) even though they remembered the photo itself (Q1: “yes”) took more than twice the time to find the photo than those who gave one of the other three answers.



(a) Time for retrieving. (b) Keyboard operation. (c) Mouse operation.

Fig. 6. Time for retrieving (a) and details of operations (b), (c) for the answers to Q2, “Did you remember its position?”

Characteristic Tendencies for Keyboard Operation: As shown in Fig. 6 (b), the rate of using the “approach” scrolling pattern for keyboard operation was significantly reduced when the degree of memorization was lower. That is, the more accurately the participant remembered the position, the easier it was for him/her to recognize when he/she was close to the target. He/she was able to move directly and rapidly toward the target because he/she knew where it was. As he/she approached the target, he/she slowed down to be able to stop directly at the target. Interestingly, when the answer to Q2 was “yes” i.e., the user remembered the position exactly, the “tap” scrolling pattern was not used. The basic strategy was to keep pressing the arrow key and moving quickly until the neighbors of the target were reached.

The characteristics for users who answered “yeah (mostly)” or “no, but remembered” to Q2 were similar. In particular, the percentages for the “pass-by” pattern were high. This was because it was more difficult for them to recognize when they were close to the target because they approximately rather than accurately remembered the position. They could find the photo visually because they knew the photo itself, so, when they found it, they immediately stopped moving and went back to the target.

When they did not remember the position (Q2: “no”), the percentage for the “alternate” pattern was more than 50%, and the two “keep-on pressing” patterns (“approach” and “pass-by”) had the smallest percentages. This can be interpreted to mean that these participants used a probabilistic search strategy. That is, by periodically changing the “base” position of retrieval, they hoped to more quickly approach and reach the target.

Characteristic Tendencies for Mouse Operation: As shown in Fig. 6 (c), when the participants remembered the position of the target exactly (Q2: “yes”) or almost exactly (“yeah”), the rate of using the “approach” pattern for mouse operation was close to 50%. The “jump” pattern was virtually unused, especially for “yes.” This means that, when the participants knew the position of the target, they moved toward it without hesitation. If they did not initially remember the position but remembered it during the operation (“no, but remembered”), the rate of using the “approach” pattern was lower, and that of using the “jump” pattern was higher. The “jump” pattern was also used by those who answered “yeah”. As evident in the figure, the lower the degree of remembering the position, the higher the rate of using the “jump” and “move-slowly” patterns. However, when the participants did not remember the position at all (Q2: “no”), the “jump” pattern was not used, and the rate of “move-slowly” was close to 50%. This can be interpreted to mean that, when a participant roughly remembered the position, he/she used the strategy of frequently changing the base position of retrieval, aiming to accidentally and probabilistically find a location near the target. And when they did not remember the position at all, they used the strategy of slowly searching from one end of the photo list one-by-one.

As we have seen, the operation patterns varied with the degree of how well the target’s position was remembered. In keyboard operation, when the participants remembered the position accurately, the typical pattern used was “approach”; when they remembered the position approximately, it was “pass-by”; and when their memory was poor, it was “alternate.” In mouse operation, when they remembered the position exactly, the typical pattern used was “approach”; when they remembered the position approximately, the “jump” pattern had a larger rate; and when their memory was poor, “move-slowly” was dominant.

5.4 Types of Photos and Operation Patterns

We have seen that there is a relationship between the degree of memorization and the operation patterns used. Then, what kinds of photos are easy to memorize and what kinds of photos are difficult? We defined “memory score” (MS) for evaluating the ease with which the photos were memorized. It was calculated for the photos for which the answer to Q1 was “yes.” MS makes use of the answers for Q2 and Q3 and is defined as

$$MS_{i,j} = \begin{cases} 3 \times q_{1,i,j} + 2 \times q_{2,i,j} + 1 \times q_{3,i,j} + 0 \times q_{4,i,j} & \text{(if answer to Q3 was “yes”)} \\ 0 & \text{(if answer to Q3 was “no”)} \end{cases}$$

where *i* stands for participants and *j* stands for photos. The $q_{1,i,j}, q_{2,i,j}, q_{3,i,j}$, and $q_{4,i,j}$ are the answers to Q2 (“yes,” “yeah,” “no, but remembered” and “no”) and took a value of 1 if they corresponded and 0 if they did not. The more accurately the participants remembered the position of the target photo, the higher the score that was awarded. If the answer to Q3, which was to confirm how accurately they remembered the position after finding the target photo, was “no,” a score of 0 was given because their memorization was not accurate. The higher the MS, the easier it was for participant *i* to memorize photo *j*.

The average MS for each photo type we used in the experiment is shown in Fig. 7 (a). The “series” photos tended to have higher scores, and the “featureless” ones tended to have lower scores. The results show a correlation between photo types and MS, i.e., ease of memorization.

We have seen that the operation patterns varied with the degree with which the photo itself and its position were remembered. Since the degree of remembrance is affected by the photo type, there must be a correlation between photo type and patterns used. This is supported by the finding that it took longer to find featureless photos (Fig. 7 (b)).

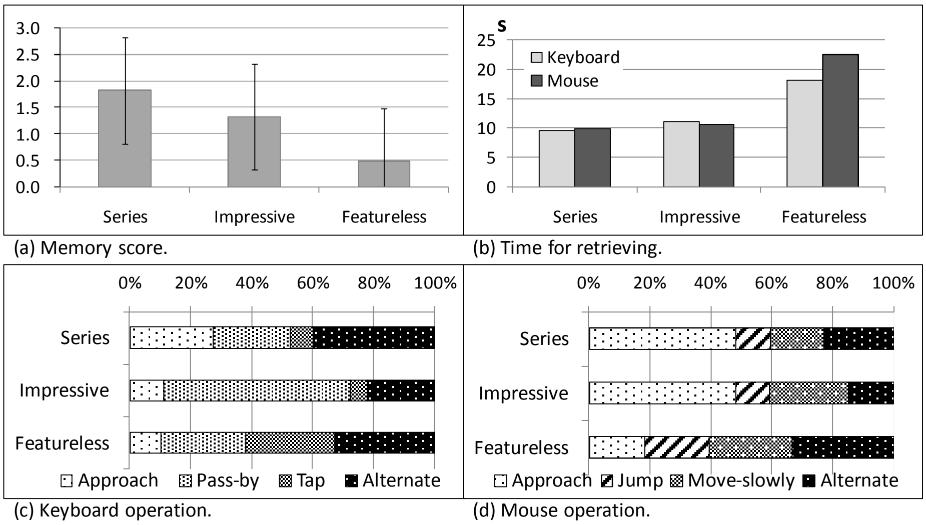


Fig. 7. Type of photo and (a) memory score, (b) time for retrieving, details of operation for (c) keyboard and (d) mouse operation.

Photo Type and Keyboard Operation: As shown in Fig. 7 (c), when searching for “series” photos, the participants used the “approach” scrolling pattern at a higher rate than for the other two types of photos. This can be explained in the sense that, when searching for a “series” photo, it was easier for a participant to recognize when he/she was in the neighborhood of the target photo even when they approached it quickly because the similar photos in the series were easily recognized. It was surprising to find that the “alternate” pattern had the highest rate (~40%) for “series” photos. This could be because, when the participant did not remember the position of the series, he/she searched for the series of photos that included the target at a medium scrolling speed (not quickly by continually pressing the key, and not slowly by using the “tap” pattern). This would be more likely to happen when the series containing the target photo contained only a few photos, and the target photo itself was “featureless.” When searching for “impressive” photos, the participants used the “pass-by” pattern at a rate of about 60%. This was because the “impressive” photos could be memorized more accurately, enabling the participants to move directly and quickly toward the target photo. However, since the target was not in a series, it was difficult to recognize when they were near the target so that they could slow down. They passed the target and then went back. The “tap” pattern was used more often to search for “featureless” photos. The participants tended to search for the target by scrolling slowly from one end of the photo list photo-by-photo because they had few clues for recognizing the photo.

Photo Type and Mouse Operation: As shown in Fig. 7 (d), the mouse operations used to search for “series” and “impressive” photos were mostly the same. In both cases, the “approach” pattern, i.e., moving the slider rapidly over a long distance toward the target, had a rate of about 50%. The difference is that the rates for “move-slowly” and “alternate” were reversed between “series” and “impressive.” For “series,” the rates were about 13 and 24%. For “impressive,” they were about 26 and

15%. This indicates that, when the participants did not know the whereabouts of the target photo accurately and searched for a series of photos, they tended to use “alternate,” so the average scrolling velocity was medium. When they searched for a single impressive photo without knowing its whereabouts, they tended to use “move-slowly,” so the average velocity was low. For “featureless” photos, the rates for “jump” and “alternate” were higher (~21 and ~32%). The search strategy was to increase the probability of finding a neighbor of the target by changing the retrieval base periodically or by suddenly beginning to move the slider.

6 Discussion

Effects of Type of Photo and Degree of Memorization: We have seen that different scrolling patterns were used depending on the degree of memorization of the target photos and of their positions in an arrangement. There was also a relationship between the type of photo and the degree of memorization. This relationship was used to define a rule combining the patterns of operations and the type of target content. The differences in the scrolling patterns can be interpreted as difference in information-retrieval strategies.

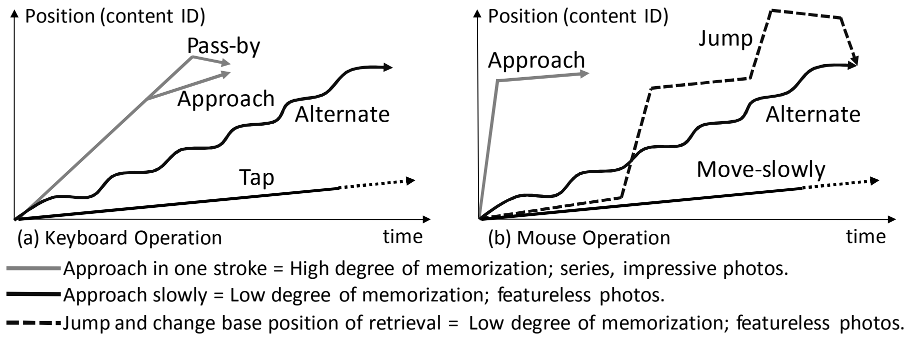


Fig. 8. Typical patterns of operations.

In our user study, we found some typical patterns of operations (Fig. 8). The “approach” and “pass-by” patterns observed for keyboard operation were consistent with the “approach” pattern observed for mouse operation. They were generally used to search for well-memorized photos that were either in a “series” or “impressive” and were not used much to search for poorly memorized “featureless” photos. For “series” photos, the searcher tended to slow down and stop at the photo. For “impressive” photos, the searcher tended to go past the target and return to it. The “tap” and “move-slowly” patterns observed in keyboard and mouse operations, respectively, were used to search for unfamiliar photos (poorly memorized and/or “featureless”).

The interesting and unexpected patterns we found were “alternate,” observed for both keyboard and mouse operations, and “jump” for mouse operation. The “alternate” pattern was used for retrieving poorly memorized photos, especially in keyboard operation. The “jump” pattern was correspondingly used in mouse operation. It tended to be used to search for poorly memorized, “featureless” photos. With the “alternate” and “jump” patterns, the participants used a similar strategy for finding unfamiliar photos. They changed the base position of retrieval, aiming to accidentally and probabilistically come close to the target. The difference between the two is that with “alternate,” the participants changed their base position periodically and generally continued scrolling in the same direction. With “jump,” they changed the base position suddenly and did not necessarily continue scrolling in the same direction, so that the position (photo ID) plot zigzagged.

Effect of Arrangement Order: We received several useful comments regarding photo memorization. For example,

1. *“I memorized the photos on the basis of the clothes the people wore or the season.”*
2. *“I knew that the target photo was not in the latter half of the photo list, even though I did not remember the photo itself. The target photo showed some houses, and although I did not remember any pictures with houses, I did recall that there were no photos with houses in the latter half of the photo list, only ones with beautiful beach scenes.”*

The first 100 of the 200 photos used in the experiment were taken in May, and the other 100 were taken in October. People with short-sleeved shirts or trees with green foliage were included in the photos taken in May, reflecting the season becoming warm. Likewise, people with long-sleeved shirts or trees with foliage that had turned red were included in the photos taken in October. Comment 1 indicates that the participant had memorized photos by using a mental model of clothes and seasons. That is, a sense of the season of the photos was mapped onto the flow of time for all 200 photos and was used to estimate the position of the target photo. Comment 2 indicates that the position of the photo could be deduced even when the participant did not remember the photo itself. The participant searched for the photo by comparing it with the order or atmosphere of all the photos to estimate its position. These comments indicate that we make use of a mental model reflecting the atmosphere of all the photos, focusing on their features and order, rather than memorizing each photo exactly. If the order of photos is changed, the atmosphere generated by the whole collection of photos is also changed. This can change the scrolling patterns or time it takes to find the target photo.

7 Conclusion

We have demonstrated that the scrolling patterns used for retrieving photos differ significantly depending on how well the searcher memorizes them and their positions in the arrangement. We also demonstrated that a photo’s characteristics affect the degree to which it is remembered. The difference in scrolling patterns can be interpreted as a difference in strategies for retrieving information. These findings enable the mechanisms used to retrieve information to be better understood, and lead to interfaces that can dynamically and appropriately assess user intentions. Our ultimate goal is to understand the mechanisms people use to retrieve information and to establish a method for designing user interfaces based on that understanding. To reach this goal, we plan to investigate the relationship between not only photos but also other contents, such as text or sound, and retrieval behaviors. In the study described in this paper, we investigated fundamentals of these mechanisms. We showed that it is possible to extract a principle of information retrieval that is based on memorization and to develop an algorithm for adapting user interfaces to human's behaviors. For example, an algorithm could be constructed that causes only photos in a series with high memorization potential to be presented with emphasis when a user scrolls through the photos rapidly and that causes featureless ones with low memorization potential to be presented with emphasis when the user scrolls slowly. Though this example is rough and the details must be worked out, if such algorithms were established, we could design interaction methods based on the natural behaviors of people rather than simply designing the outer layer or a brand-new input method or defining functions that treat the relationships between the various factors and the search behaviors in the same way.

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