# Study on Haptic Interaction with Maps

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**Abstract.** Although older adults' haptic interaction with a paper map (HIM) has been observed in our previous studies, the effectiveness of touch panel operation introducing HIM was not addressed. In this study, young adults' characteristic hand movements were observed, and the hand movements to understand the present location and directions to a goal by a walker as the HIM were defined. Hence, a digital map with three HIM functions was developed and the effectiveness of these functions was measured and experimentally clarified. Further, the effectiveness of a prompted HIM was experimentally investigated using a specific digital map that prompted various HIM on the walker's demand. Finally, the characteristics of HIM and the effectiveness of prompting HIM to the walker using a map were clarified.

**Keywords:** haptic interaction, paper map, digital map, touch panel, tablet PC.

## 1 Introduction

### 1.1 Background

Our previous research [1], [2] has shown that the Japanese elderly have an aversion to using personal computers (PCs). Therefore, we conducted a usability study of our specific digital evacuation-route map on personal digital assistants (PDA) with a touch panel for the Japanese elderly. Almost none of the older participants could get to the goal using the digital map, but they were able to do so using a paper map. Hence, we observed the participants' behavior using the digital evacuation-route map and compared this interaction with the behavior when they used a paper evacuation-route map. The results suggested that a participant's hand motion on the paper map is for route planning and understanding the present location [3].

The importance of object attributes for haptics and haptic exploration has been previously considered [4-6]. However, the hand movement on the paper map was not intended to explore the attributes of the paper map, such as smoothness or texture, but was for understanding the present location and visualizing the route toward a goal. Furthermore, the hand movement occurred either at the unconscious level or consciously with think-aloud protocols. Thus, we regard the hand movements as a type of haptics with paper map and we have named the meaningful hand movement for interacting with the map as *haptic interaction with map* (HIM).

S. Yamamoto (Ed.): HIMI/HCII 2013, Part I, LNCS 8016, pp. 62–71, 2013.

We assumed that HIM was useful for walking when checking a paper map for direction, and also that HIM would not be useful for a digital map on a PDA with a touch panel. Although the older participants knew how to use the digital evacuation-route map, they consciously or unconsciously tried HIM with the digital evacuation-route map. Hence, the older participants caused unintentional behavior of the digital evacuation-route map and confused themselves. It appeared to us that the confusion accumulated and the older individuals gave up walking to the goal using the digital map. However, the touch panel is a mainstream interface for portable information devices such as tablet PCs. Therefore, the style of digital map operation should be taken into account based on unintentional hand movements such as HIM for the Japanese elderly.

On the other hand, it is not clear that HIM is common for young Japanese individuals who have become familiar with smartphones. Further, how the HIM of young individuals using a digital map affects or effects their context of use is not clear.

### 1.2 Objective

The purpose of HIM is not to understand the physical properties of paper or a tablet PC touch panel, but for getting information from a paper map or the screen of a tablet. Although we can see that HIM is map-reading skill, we assume that the important characteristics of HIM for getting information by moving the hands, fingers, arms, and so on are similar to those using the haptic interaction with physical mattes. Thus, the aim of our study is to experimentally clarify the characteristics of HIM and its effect on users when reading a paper or a digital map. Although our previous studies [2] indicate that the Japanese people, especially the elderly, have very wide range capabilities when using information technologies, we focused on the HIM of young Japanese in this study.

## 2 Method

To clarify the characteristics of HIM in young individuals, our research was conducted according to the following steps.

### 2.1 Observing and Extracting HIM of Young Individuals

The hand movements of young individuals who tried to walk to a goal using a paper map were experimentally observed, and their HIM was extracted. The extracted HIM of the young was compared with that of the elderly we had previously investigated.

In the trial, four male and five female individuals who ranged from 20 to 22 years of age participated. The participants tried to walk using a paper map in a residential area. Two types of colored paper maps were prepared and used. One was A4-sized, printed on a scale of 1 to 3000, and easy to read, while the other was A3-sized, printed on a scale of 1 to 25000, and difficult to read.

The participants were given two tasks, i.e., to walk from different locations to the goal using the two maps, once each time. Each task had to be done within 40 min, after which the trial ended, regardless of whether the goal was reached or not. Further, we defined some roads to be impassable but told the participants to draw back only at the point when they tried to pass through it. As a result, the participant had to replan the route to the goal while referring the paper map.

Two investigators followed the participants and an investigator recorded the participants' behavior such as hand movement, expression, and think-aloud protocols using a video camera. The other investigator noted the remarkable hand movements and interviewed the participant about these hand movements after the trial.

The HIM of the participants was extracted from their various hand movements based on the experimental data such as the recorded and noted behaviors. In particular, we investigated the relation between the manner of hand movement and the participants' performance data such as the walking distance and the time taken to arrive at the goal.

## 2.2 Introducing HIM into Digital Map Operation

The extracted HIM of the young participants was introduced into the operation of the digital map by making specific digital software for the tablet PC (MSI Winpad 110W-017JP). The tablet PC ran Windows 7 Professional Japanese Edition and had a 10-inch display touch panel. Although the map on the tablet PC was made based on an easy-to-read map scale, the scale of the map could be changed by pinching in/out touch operation and it could be scrolled by running a finger on the touch panel. Furthermore, to express the HIM marks such as tracing along a road or applying pressure with fingers, we developed functions (HIM functions) that visualized HIM on the map in terms of lines and dots. The HIM functions were available when the user touched the center button. However, the map could not be rotated by the user.

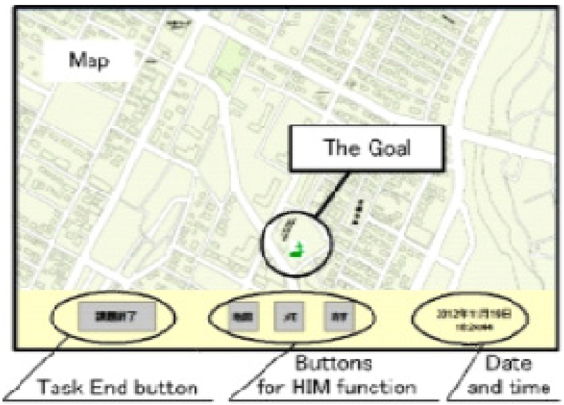


**Fig. 1.** Screen of specific digital map with touch panel

To observe HIM using our specific digital map, we conducted an experiment in a manner similar to the prior experiment using the paper maps. However, we made two versions of the digital map available on the same tablet PC to compare the participants' behavior and the performance for cases in two cases: (i) when the HIM functions were available and (ii) when they were not. The participants were three male and three female students who ranged from 19 to 22 years of age. We prepared two tasks (Task-A and Task-B) for the participants: to walk from two different locations to the goal using the two types of digital map, with or without HIM functions, once each time. Three participants tried Task-A using the digital map with the HIM functions, followed by Task-B using the digital map without the HIM functions; the other three participants tried Task-B using no HIM functions followed by Task-A using HIM functions.

The area for the experiment was a residential area in Chitose, Hokkaido, Japan, but different from the area used in the prior experiment. Each task had to be done within 30 min, after which the trial ended, regardless of whether the goal had been reached or not. Further, we defined some roads as impassable and told the participants to draw back only when they tried to pass through it. Consequently, they had to replan the route to reach the goal using the digital map.

Two investigators followed the participants and an investigator recorded the participants' behaviors such as hand movement, expression, and think-aloud protocols using a video camera. The other investigator noted the remarkable hand movements. Furthermore, the investigator interviewed the participant about the reason or meanings for characteristic hand movements, including touch operations, after the trial and if the participant could recall the particular hand movement.

The experimental data were analyzed and compared for both the cases by using and not using the HIM functions to clarify the relationship between HIM on the digital map and the participants' performance such as walking distance.

### 2.3 Investigation of HIM's Effectiveness Suggested by Digital Map

It seems logical that a user who confidently accesses a digital map by operations or manipulations, including HIM, will get the appropriate information required to walk toward a goal. This point gives rise to the hypothesis that prompting for HIM leads to a walker's successful decision-making and appropriate performance such as walking in the right direction without confusion. Hence, we experimentally confirmed this hypothesis using another specific digital map that prompted for the correct HIM on demand.

The specific digital map prompting HIM was made based on the prior specific digital map by adding the new feature that prompts the HIM on demand. If a walker became disoriented with the digital map, touched a "Need Help" button on the screen, and selected a context menu item from "Not certain of current position," "Lost all sense of direction," or "Planned route has been lost," then the digital map took into consideration the participant's situation and indicated a message prompting the applicable HIM, as shown in Fig. 2.

The effectiveness of the specific digital map with HIM prompting was tested by eight participants who ranged from 20 to 21 years of age. The participants were divided into two groups and the conditions for using the digital map with and without prompting the applicable HIM were tested based on the counterbalanced measures' design.

The area the participants walked in and the acquisition of experimental data were the same as the previous experiment.


**Fig. 2.** Example of screen prompting the applicable HIM

# 3 Results and Discussions

## 3.1 Extracted HIM

From the data of the observational experiment for extracting the young participants' HIM, the meaningful hand movements recorded by video were extracted from the testing the effectiveness of the participant's map reading and/or route planning. Eight different hand movements were observed without any significant gender bias, as shown in Fig. 3.

From the participants' opinion, we assumed that four types of hand movements—"Turning," "Flipping," "Folding," and "Unfolding"—suggested managing the paper map to facilitate visualization, and the other four types—"Orienting," "Tracing," "Pressing," and "Writing"—were useful hand movements to decide the direction to reach the goal, understand the present location, and plan the route to the goal. Hence, we designated these three types of hand movement HIM to stimulate map understanding. The movement-type "Writing" was extracted from the behavior of a female participant who had a pen by chance; she wrote a line marking her planned route to the goal and also marked her location. Therefore, her aim when "Writing" was similar to the functions of "Tracing" and "Pressing."

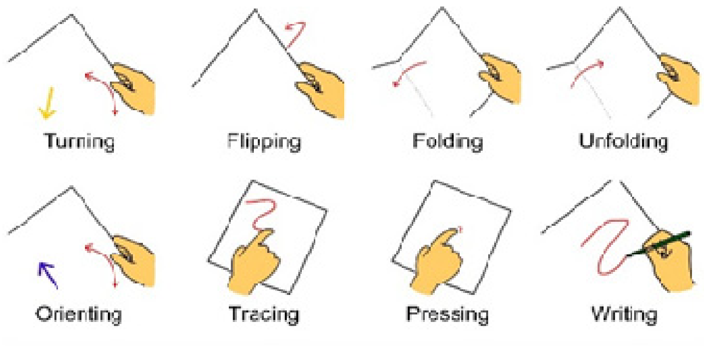


**Fig. 3.** Observed hand movements

Consequently, we extracted three different HIM for the paper map and applied them to the digital map operation to allow using the digital map as if the user manipulated a paper map. “Orienting” was made possible by the antirotation map on the screen; “Tracing,” “Pressing,” and “Writing” were made possible by the drawing function on the map when pressing or running a finger. With the exception of “Writing,” the other three types of HIM were coincident with the older adult’s HIM that we had observed in the previous studies, and we developed a digital map implementing these three types of HIM using a function. We then evaluated how the participant’s performance was affected by the availability of the HIM function.

### 3.2 Effect of Digital Map Operation Including HIM

The participant’s performance, measured by walking distance for Task-A and Task-B, was compared for the two cases: when the HIM function was available and when not available. The results showed that the minimum walking distance for Task-A was 878 m and that for Task-B was 737 m. From the statistical results of the one-side test, the walking distance for users having a tablet PC with the HIM function was significantly shorter ($p = 0.04$) than that for users who are unable to use the HIM function in Task-A (Fig. 4), but it did not differ significantly ($p = 0.41$) for Task-B. Although the results for Task-A suggested that the participants using the HIM function took some shortcuts to reach the goal and the walking distance is significantly shorter, the minimum walking distance for Task-B is 141 m shorter than that for Task-A. Therefore, we think that taking a shortcut by the participants is not a significant factor for the results on the right-hand side of Fig. 4.

According to the video-recorded behavior of the participants, two female students did “Orienting” on the digital map just as for a paper map. These students said that they did “Orienting” on the digital map to face in the direction they were going. One other female student and a male student also did “Orienting” unconsciously when they were confused on the way. On the other hand, all the participants did “Tracing” and “Pressing” by using the HIM function to draw tracks and mark the impassable road on coming across it. Further, two male students and a female student used the HIM function for drawing the planned route to the goal as necessary.

Although the participants recalled nearly all of their HIM, we interviewed them about the effect of HIM after the trials. As a result, we know the effect of the respective types of HIM on the participant's decision-making with respect to moving toward the goal and gaining more confidence in understanding their location and direction, as shown in Table 1. Table 1 shows a specific example of the effect of HIM and the related HIM the participants pointed out; the number shows how many participants relate a specific example of an effect to the HIM-type.

As a consequence of these experimental results, we know that the participants used the HIM function for memorizing or better understanding their path and/or the planned route toward the goal; therefore, HIM is useful for walkers with a map to some extent. However, the aim and style of HIM varied a little among the participants. In fact, some participants did not perform "Orienting" at all, and all the participants did not use the same types of HIM for the same purpose.

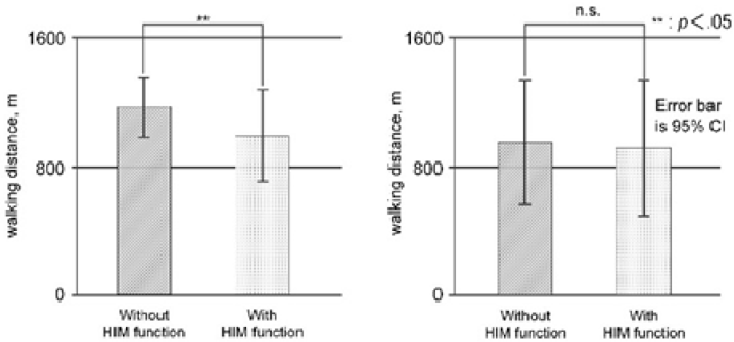


**Fig. 4.** Walking distance for Task-A (left) and Task-B (right) by the participants

**Table 1.** Specific example of the effect of HIM given by the participants

| Specific example of the effect | Related HIM-type | | |
|---|---|---|---|
| | Pressing | Tracing | Orienting |
| Understanding the present location, the goal, or the landmark well | 6 | 2 | 0 |
| Gaining more confidence in understanding the present location and/or the direction toward the goal | 2 | 4 | 5 |
| Planning the route to the goal | 0 | 2 | 0 |
| Understanding the path taken from the starting location | 0 | 2 | 0 |

### 3.3 Effectiveness of HIM Suggested by Digital Map

We designed the digital map function prompting appropriate HIM in the user's context based on the knowledge about the HIM and its effect. Fig. 2 shows the three context menu items on right-hand side of the screen and the suggestion for the appropriate HIM based on the user's situation.

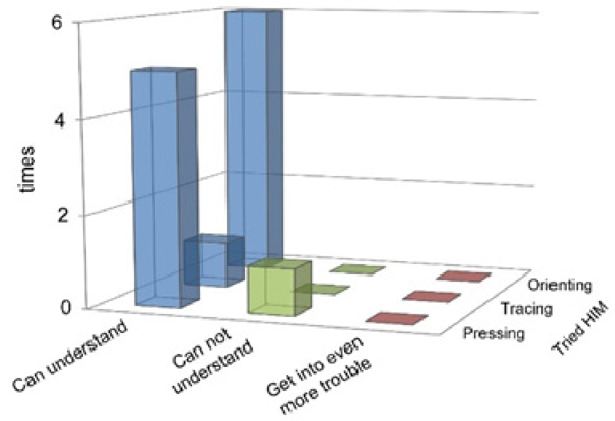


**Fig. 5.** The participant's situation after trying prompted HIM

The results show that the difference in the walking distance between two cases—(i) using the prompted HIM and (ii) without using the prompted HIM—was not statistically significant for the respective tasks; therefore, it can be said that HIM prompted by a message did not have a direct benefit on a walker's performance. Next, we focused on the participant's verbal protocol data when the participant was in trouble and tried the prompted HIM. Fig. 5 shows the outcomes of 13 situations when a participant was in trouble, touched the "Need Help" button, and tried the prompted HIM. The participants could grasp the key to adjust their understanding in almost all the cases by trying the prompted HIM.

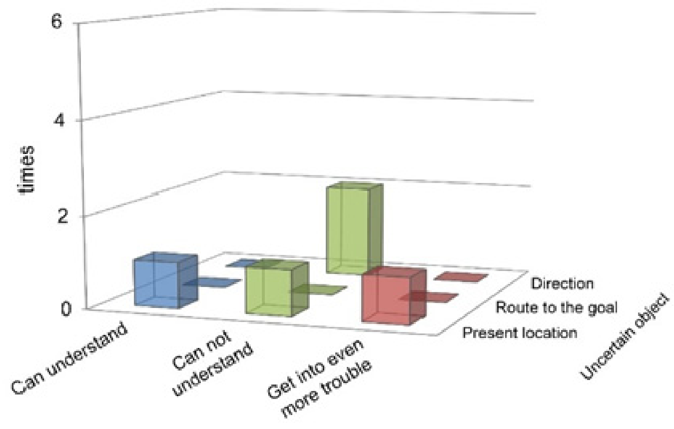


**Fig. 6.** The participant's situation after using the digital map without prompted suggestions

On the other hand, in five situations, we saw that participants were confused or were in trouble using the verbal protocol data on the digital map that prompted nothing; however, few participants could get help, as shown in Fig. 6. Therefore, prompting HIM is effective in difficult situations for walkers from the perspective of their cognitive processes.

Consequently, we conclude from this experiment that intentional HIM is useful for getting more information from the map, although haptic interaction is for getting the characteristics of physical mattes. In fact, we could see that HIM is a type of map-reading skill. Therefore, digital map operation should be designed based on HIM.

## 4 Conclusion

From the results obtained from this work, we know that the different types of HIM in young individuals is same as that of the Japanese older adults observed in previous studies; therefore, we may say that the three types of HIM including “Orienting,” “Tracing,” and “Pressing” are common in the Japanese people. However, the effect of these HIM types on decision-making for movements differed among the participants. From the experimental results, we assume that the effect depends on various factors such as the context of use rather than HIM, and therefore, HIM directly affects the performance measures such as walking distance.

Another question is whether or not intentional HIM and unconscious HIM lead to the same result. In this study, we focused on the intentional HIM rather than on the unconscious HIM because the latter is difficult to observe through experiments. However, some participants were pointed out as using their unconscious HIM by the investigators, and they said that the unconscious HIM was not effective because it was the result of a confused situation. Therefore, when unconscious HIM such as “Turning” is frequently observed, it implies that the walker could be confused.

This study also indicates that the intentional HIM is effective; however, digital maps do not allow the observation of intentional HIM because of the common style of touch operation. Thus, the touch-panel operation for digital maps should be redesigned by referring to HIM, at least for the Japanese elderly.

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