Spatial Cognition and Intentional Behaviors in the Post-Sedentary Age

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Abstract
The purpose of this study is to offer new insight into architectural and urban planning in the post-sedentary age. Specifically, we reveal the characteristics of walking in cities with mobile networks. The experiment involved strolling around the old town of Tokyo with 20 participants divided into two groups: (1) Those who could use smartphones and (2) those who could only use printed maps. The participants' behaviors were recorded by GPS data loggers and analyzed by GIS in terms of the following three aspects.

First, we estimated the features of walking according to the lengths of time participants collected information and the contents of that information and reached the conclusion that walking within mobile networks was deliberate. Second, we analyzed the efficiency of walking using the redundancy index and concluded that different kinds of behaviors can be confirmed depending on the time available to complete tasks. Third, we explored walking with curiosity in terms of the various types of roads where participants walked and inferred that walking in a mobile network environment reduced anxiety regarding losing one's way and aroused much curiosity.

Keywords: strolling; smartphone; walking experiment; GPS

1. Introduction
In touring cities, we have only been able to obtain necessary information from printed maps and guidebooks or on-site signs and guide plates. However, the popularization of mobile networks has changed the nature of our strolls. Even in unfamiliar areas, we can search for and recognize famous sightseeing spots or popular shops and restaurants by using smartphones quickly from anywhere. In addition, we can easily visit these facilities using the detailed routing information displayed on the mobile devices. William Mitchell (2003)1 summarized these social changes and the revolution created by urban information overlays and named it "post-sedentary" from a broader standpoint of informatization.

Spatial cognition and behavior in the post-sedentary age may also affect the concept of architectural and urban planning, but few studies provide tangible suggestions based on the actual conditions. Therefore, the negative effects of informatization are discussed, such as digital divide issues and the decline in real space. However, the real-time gathering of local information may enhance visitors' migration and may become an effective means for promoting shopping districts and sightseeing destinations.

Nomura and Kishimoto (2006)2 demonstrated the efficiency of using GPS and GIS in analyzing visitors' behavior and activity through their experiment at a famous sightseeing area in Kamakura City. With their observations of primary school children's behavior after school, Sugihara, Matsushita, and Munemoto (2010)3 have developed a more effective method for clarifying human behavior in urban environments, using GPS, compared with the previous interview and questionnaire methods.

Other studies regarding the development of mobile navigation systems occasionally conclude that the use of these systems is effective for path-finding and affects users' behavior. Tatenami, Matsushita, and Munemoto (2006)4 measured the level of anxiety (LOA) in wayfinding with pedestrian navigation systems and concluded that LOA was highly influenced by the identification of the point of interest and directly influenced by the experience of the route in the past.

Kobayashi and Koike (2010)5 determined that the provision of information by ubiquitous technology affects peoples' decisions, expands the ranges of their strolling, affects their migrations, and, accordingly, contributes to the lengths of time they stay. The Japanese government and private companies have also conducted questionnaire studies and pilot programs.
to investigate the activities of the information age and have insisted that migration behavior is strongly related to on-site, real-time information\(^6\).

However, these studies on walking within mobile networks were confined to the passive use of the specific services for the mobile phones provided by the experimenters. These days, with the popularization of smartphones, we routinely select and use favorite Internet services actively from anywhere. Spatial cognition and behavior in the post-sedentary age can be characterized by the active use of smartphones.

2. Objectives

In this study, we focus on the active use of mobile networks rather than the passive uses mentioned in the previous studies. From the assumption that mobile networks activate human behaviors in real space, we clarify the differences between spatial cognition and behavior in the presence or absence of a mobile network based on the experiment of strolling in an unfamiliar area.

3. Outline of the Experiment

According to the bibliographic survey and preliminary examinations, the following three aspects were configured for the experiment in the mobile network: (1) planning of walking routes, (2) efficiency of walking, and (3) walking with curiosity.

The experiment was performed in the old town of Tokyo called Yanesen. Many temples, shrines, and traditional retail shops can be found in this area, which was recently recognized as a major sightseeing spot (see Fig.1.).

In order to capture the progress of informatization, the participants were selected from the young generation called "digital natives" to gain insight into future architectural and urban planning. Seventy-eight men and women in their early 20s who frequently used the Internet participated in the experiment. All of them were students of the same university located far from the experiment area.

First, to ensure the similarity of participant characteristics, we administered a preliminary survey that assessed the participants' interest in strolling in cities, their experience of strolling in this area, and so on (see Table 1.).

Table 1. Survey Questions

| No. | Usual information source | Average number of times the Internet is used per day | Frequency of Internet use while walking | Home town | Current resident status | Frequency of visiting downtown Tokyo | Typical number of members who stroll together | Frequency of strolling in cities | Areas of familiarity | Length of time the smartphone is used |
|-----|--------------------------|--------------------------------------------------|--------------------------------------|-----------|------------------------|-------------------------------------|------------------------------------------|-------------------------------|------------------|-------------------------------------|
| 1   | Usual information source | Average number of times the Internet is used per day | Frequency of Internet use while walking | Home town | Current resident status | Frequency of visiting downtown Tokyo | Typical number of members who stroll together | Frequency of strolling in cities | Areas of familiarity | Length of time the smartphone is used |

Based on the results of this questionnaire, 20 participants were selected in an unbiased manner and divided into two groups: (1) Those who could use smartphones, named the "net group" and (2) those who could only use printed maps, named the "map group" (see Table 2.). All of them were born in and had grown up outside of Tokyo, used smartphones on a daily basis, preferred strolling alone, and sometimes visited downtown in Tokyo but had never walked around the experiment area.

The experiment was conducted in the following order in the autumn of 2009.

Table 2. Participants List of the Experiment

| Net Group | Map Group |
|-----------|-----------|
| No. | Sex | Date | Weather | Time | No. | Sex | Date | Weather | Time |
| N-1 | M | Oct. 13 | Fine | 14:00 to 16:00 | M-1 | M | Oct. 13 | Fine | 13:00 to 15:00 |
| N-2 | M | Oct. 15 | Fine | 12:00 to 14:00 | M-2 | M | Oct. 13 | Fine | 15:00 to 17:00 |
| N-3 | M | Oct. 20 | Cloudy | 14:00 to 16:00 | M-3 | M | Oct. 15 | Fine | 13:00 to 15:00 |
| N-4 | M | Oct. 20 | Cloudy | 13:00 to 15:00 | M-4 | M | Oct. 20 | Cloudy | 13:00 to 15:00 |
| N-5 | W | Oct. 20 | Cloudy | 14:00 to 16:00 | M-5 | W | Oct. 20 | Cloudy | 15:00 to 17:00 |
| N-6 | W | Nov. 24 | Cloudy | 10:00 to 12:00 | M-6 | W | Nov. 23 | Cloudy | 10:00 to 12:00 |
| N-7 | W | Nov. 24 | Cloudy | 11:00 to 13:00 | M-7 | W | Nov. 29 | Cloudy | 10:00 to 12:00 |
| N-8 | W | Nov. 24 | Cloudy | 12:00 to 14:00 | M-8 | W | Nov. 29 | Cloudy | 11:00 to 13:00 |
| N-9 | M | Nov. 25 | Cloudy | 10:00 to 12:00 | M-9 | M | Nov. 25 | Cloudy | 10:00 to 12:00 |
| N-10 | M | Nov. 25 | Cloudy | 11:00 to 13:00 | M-10 | M | Nov. 25 | Cloudy | 11:00 to 13:00 |

![Fig.1. Experiment Area](image-url)
Step 1. Explanation of the rules for strolling
(approximately 10 min.)
A time restriction and two tasks were assigned in order to prevent participants from excessive strolling. The tasks were to purchase a nice souvenir for a close friend and to search for a book on the Yanesen area, both common activities for strolling in a city. The participants gathered at the Sendagi subway station and were asked to complete these tasks along the way and to return to the station within one hour.

Step 2. Strolling
(approximately one hour)
All participants wore GPS data loggers on their waists in order to record their walking routes in detail. Smartphones (specifically, iPhones) were provided to the members of the net group so they could browse the Internet freely, and maps of the Yanesen area published by the town development organization were provided to the members of the map group.

Step 3. Post-stroll questionnaire
(approximately 30 min.)
After the experiment, participants were administered a questionnaire on their reasons for stopping at certain places, their impressions of strolling, and other items that could not be derived from the GPS log data.

4. Results of the Experiment
All data were gathered from the 20 participants in Table 2 and analyzed by ArcGIS. Fig.2.-1 illustrates the stroll routes of the net group participants, and Fig.2.-2 illustrates those of the map group participants. We did not quantitatively measure the flow of human traffic along their routes, but none of them were crowded during the experiments. We also confirmed with all participants that they could walk around freely and that their behaviors were not affected by the flow of human traffic.

The indicative values of strolling were summarized and the average values of the two groups are presented in Table 3.

1. Strolling
Because the participants were given a time limit, the total strolling time was approximately 75 minutes for both groups and there was no significant difference. However, in terms of walking distance, the map group walked approximately 500 meters more than the net group. Behaviors consistent with getting lost were confirmed in some participants of the map group, and might account for the difference in walking distances as shown in Fig.2.-2.

2. Dropping in
On every index, the net group marked higher average values than the map group. In addition, the net group participants frequently stopped at the characteristic temples and shrines of the Yanesen area, whereas the map group participants mostly stopped at the shops along the main streets.

With respect to the tasks, the map group participants did not use the provided Yanesen maps to fulfill them; they mostly stopped in at shops they just happened to pass. On the other hand, the net group participants decided what shops to stop in at on the basis of the information they collected, and many of them visited secluded shops.
3. Collecting Information

The net group participants spent a significant amount of time collecting information throughout their strolls. The map group participants mostly used the Yanesen map they were given in order to confirm their orientation but did not use it for traveling to the specific facilities.

The net group participants mostly used keyword searches on Safari and Google Maps to collect necessary information; they hardly used the specific smartphone applications. After they searched by keywords related to the tasks, such as "Yanaka," "Sendaki," "sweets," and "book," they followed links from one page to another and found information that met their purposes.

5. Analysis of the Result

5.1 Walking by Design

In this section, we propose that mobile networks enable participants to walk by design. Whether the walking behavior is intentional can be estimated according to the information collected throughout their strolls, including lengths of time of their searches and the contents of the information. In order to achieve these determinations, the timing diagrams are depicted in Fig.3.

In these diagrams, the sessions of walking, dropping in, and collecting information are drawn continuously, and the relationships between the different behaviors can be confirmed. The diagrams indicate the percentage of each session within the total strolling times, because there were rarely any differences between the total times.

The results indicate that the participants tended to spend time collecting information at the start point and then again after stopping at certain sites. Specifically, the net group participants spent time searching surrounding facilities, whereas the map group participants spent time confirming their locations. Both groups of participants confirmed their locations along the way in a short period. This means that the participants who were using the mobile network planned their routes as often as they stopped in at particular places.

After detailed analysis of participants' stopping in at certain facilities according to the referenced information, these visits were classified into three patterns and the differences among the groups were ascertained.

| Table 3. Average Values of the Two Groups |
|-------------------------------------------|
| Strolling                                  | Net Group | Map Group |
| Total Time (TT)                           | 75.3 min. | 74.7 min. |
| Walking Distance                          | 4602 m    | 5108 m    |
| Dropping in                                |           |
| Numbers of Facilities                     | 5.2       | 3.8       |
| Staying Time (ST)                          | 17 min. 40 sec. | 9 min. 57 sec. |
| ST/TT                                     | 22.9%     | 13.4%     |
| Major Facilities of Dropping in           | Shop, Temple, and Shrin | Shop, Bookstore |
| Collecting Information                    |           |
| Collecting Time (CT)                      | 12 min. 27 sec. | 6 min. 29 sec. |
| CT/TT                                     | 16%       | 8.4%      |

Pattern 1: Information from the network (the net group) or information from the map (the map group).

Pattern 2: On-site information such as signs and retail store characteristics.

Pattern 3: Information from the experience of walking along the stroll route.

With respect to the number of facilities where participants dropped in, 54.7% of the net group's behaviors belonged to Pattern 1, whereas 86.8% of the map group's behaviors belonged to Pattern 2. With respect to the times participants stayed at facilities, a similar result was observed.

5.2 Efficiency of Walking

In this section, we propose that mobile networks enable participants to walk efficiently. The redundancy index proposed by Arakawa and Kamata (2002) was introduced to measure the efficiency of walking: walking distance divided by the shortest distance between the sites participants visited. Therefore, the smaller the index, the more efficient the walking.

Table 3. presents the values summarized according to behavioral categories; every index of the net group was lower than that of the map group. This is
a natural consequence of the fact that the net group participants could confirm routing information using their smartphones. However, although infrequently, some participants of the net group (N-5 and N-8) made mistakes regarding their orientation and lost their way even when using the smartphones. This behavior could be confirmed particularly at the beginning of their strolls. The participants also realized their mistakes in a short time and then walked without a moment’s hesitation. If they had not strayed around, the difference in the redundancy indexes between the two groups would have been slightly increased.

Here, we consider how the participants collected information in order to accomplish the tasks. The scattered diagram between the times of dropping in and the redundancy index is shown in Fig.5., and the behaviors can be divided into two groups at roughly the 40-minute point.

With regard to the former behaviors (Pattern 1), participants quickly stopped in at the shops listed earliest in their search results. On the other hand, in terms of the latter behaviors (Pattern 1), participants deliberately collected information from several search sites.

5.3 Walking with Curiosity

In this section, we consider whether the net group participants’ curiosity was aroused by their collecting local information from the mobile network. Here, walking with curiosity was estimated from a variety of road categories; all roads where participants walked were divided into 80 segments according to their widths and zoning codes and classified into six categories, that is, main road, shopping street, residential road, approach way, alleyway, and others. Then the walking times of individual segments were measured from the GPS log data, and the rates of each category were calculated.

Table 4 presents the group averages of each category. The net group values are relatively low compared with the map group values in the main road and residential road categories, but there was little difference in the other categories. Individually, all participants in the

Table 3. Redundancy Index

| Category      | Net Group | Map Group |
|---------------|-----------|-----------|
| N             | Average   | STD       | N   | Average | STD       |
| All facilities| 51        | 2.046     | 36  | 3.253   | 3.333     |
| Quota         | 20        | 2.374     | 20  | 3.309   | 2.170     |
| Pattern 1     | 29        | 2.160     | 4   | 5.388   | 3.287     |
| Pattern 2     | 20        | 1.888     | 31  | 2.248   | 3.406     |

Table 4. Walking Rates

| Segment      | Net Group | Map Group |
|--------------|-----------|-----------|
| Main Road    | 59.1%     | 70.0%     |
| Shopping Street | 23.9%    | 23.3%     |
| Residential Road | 3.7%     | 8.8%      |
| Approach Way | 16.6%     | 17.2%     |
| Alleyway     | 12.5%     | 11.0%     |
| Others       | 10.0%     | 5.4%      |
net group walked on various types of roads, whereas participants of the map group did not walk actively, with the exception of one (M-10) who walked in an alleyway for a long while, as shown in Fig.6.

However, the net group participants could have been following the routing information from the mobile network. Considering that the net group participants took clues from the network (Pattern 1) for approximately 54.7% of their behaviors, it is insufficient to evaluate the walking with curiosity using only the above rate.

Therefore, the rates of each category were calculated within the limits of their behaviors on the basis of the on-site information (Pattern 2). As a result, we can confirm the characteristics as shown in Fig.7. Even when they did not use the information from the network, the net group participants walked on various types of roads after they completed their tasks. That is, the mobile network allayed participants’ fear of getting lost and enabled them to walk actively in an unfamiliar area.

6. Conclusion
Throughout the analysis of the experiment, we obtained the following results with respect to the three aspects of people’s behaviors influenced by mobile networks.

1. Walking by design
Mobile networks promote collecting information and behaving intentionally as often as one drops in at various facilities. Rapid spatial cognition appears to facilitate strolling.

2. Efficiency of walking
Mobile networks encourage efficient strolling, but the different types of behaviors depend on the time available to complete tasks. Accurate information from Internet searches strongly affects one’s ability to complete tasks in a short time, whereas information from multiple searches and in actual spaces was observed to make accomplishing tasks take longer.

3. Walking with curiosity
Participants carrying smartphones predominately walked on a variety of roads, particularly after their tasks were completed. Looking at participants who stopped in at locations without inductive information, mobile networks helped them overcome resistance to unfamiliar areas, even when the networks were not used.

This can be confirmed by the various indexes in Table 3. That is, mobile networks are an effective means for the activation of real space.

The results of this study are based on an experiment performed with only 20 participants. However, the participants were selected from 78 candidates based

| N-1-1 | N-1-2 | N-1-3 | N-1-4 | N-1-5 | N-1-6 | N-1-7 | N-1-8 | N-1-9 | N-1-10 |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| before quotas | before quotas | before quotas | before quotas | before quotas | before quotas | before quotas | before quotas | before quotas | before quotas |
| 69.1 | 32.4 | 100.0 | 100.0 | 57.1 | 45.5 | 12.5 | 17.7 | 4.5 | 6.8 |
| quotas | quotas | quotas | quotas | quotas | quotas | quotas | quotas | quotas | quotas |

| M-1 | M-2 | M-3 | M-4 | M-5 | M-6 | M-7 | M-8 | M-9 | M-10 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| before quotas | before quotas | before quotas | before quotas | before quotas | before quotas | before quotas | before quotas | before quotas | before quotas |
| 33.7 | 23.6 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| after quotas | after quotas | after quotas | after quotas | after quotas | after quotas | after quotas | after quotas | after quotas | after quotas |
| 22.3 | 22.3 | 10.1 | 6.1 | 4.4 | 38.6 | 30.5 | 46.2 | 21.0 | 22.4 |

N-1-1 indicates the first dropping in of the participant N-1 G indicates the goal.

Fig.7. Individual Walking Rates of Pattern 2
on a preliminary survey, and selection bias was minimized. Statistically significant differences in the numbers of places where people stopped, the lengths of time they stayed, and the time they spent collecting information could be confirmed between the two groups at a level of significance of 5%.

A number of trials are also required to ensure accuracy. Based on the insights gained, deeper consideration is expected if this survey is expanded in a future study.

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