Relationship between Anxiety and Location Confirmation by Mobile Devices during Route Searches in Urban Spaces -Empirical Study by Application of Protocol Analysis-

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Abstract: This paper examines the relationship between the knowledge of one's current location shown by GPS and anxiety. Pedestrian navigation systems on smartphones are assumed to enable us to visualize our current location and make route searches while walking much easier, although the relationship with our mental state while walking has not been studied in detail. In order to investigate how mental states differ while walking when using pedestrian navigation systems or maps for route searches while walking, we applied protocol analysis to the differences in remarks made by subjects while walking towards a destination in a real urban space. The results showed no large difference in the ratio of the number of anxious remarks between the use of maps and the use of pedestrian navigation tools. The points at which anxiety occurred depended on the tool used, and the pedestrian navigation did not necessarily reduce the anxiety of users compared with when using a conventional map. These results suggest that the hypothesis in this research that pedestrian navigation systems, which are usually considered to be convenient, may raise different types of anxiety in the users' minds from paper maps is reasonable.

Key words: State of Mind, Variance analysis, Cognitive maps, Pedestrian navigation systems on smartphones, Shimokitazawa district in Tokyo, Spearman's rank-order correlation

1. Background and objectives

Today, we cannot imagine the world without smartphones and GPS. Smartphones and GPS are ubiquitous. According to the statistics of the Ministry of Internal Affairs and Communications of Japan in 2017¹⁾, the penetration rate of smartphones equipped with GPS exceeded 90% in people in their twenties and thirties. Pedestrian navigation systems (PNS) on smartphones use GPS to show our current location dynamically on a digital map and guide us along a route to our destination while walking in urban spaces. As the use of PNS in smartphones spreads and GPS advances, our route searches while walking are becoming easier, and this change is affecting how we value urban spaces. For example, the commercial potential of a location will increase if it can be easily reached using pedestrian navigation even if the location is difficult to find visually in the urban landscape.

However, the route information obtained by pedestrian navigation may be different from that

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Table 1: Results from previous studies

	User of Pedestrian Navigation	User of Conventional Paper Map
Memory of buildings of city ⁵⁾	Not so good	Good
Memory of the places of buildings ⁵⁾	Not so good	Good
Persistence of memory ⁵⁾	Bad	Good
Change of gazing point ⁶⁾	They focus on screen always.	They watch all around.
Accumulation of memory ⁵⁾	Bad	Good
Utilization of past memories ⁷⁾	Bad	Good
Action for real space ²⁾⁴⁾⁶⁾	Only passive actions	Active actions

obtained by conventional paper maps from the viewpoint of the mental state of the users, who may experience anxiety when searching for the route while walking. Recent articles related to whether paper maps can be replaced with information devices such as smartphones are shown in Table 1. Among articles on the behavior of subjects during route searches while walking with PNS and paper maps, Hirai ²⁾ and Ishikawa ^{3) 4)} focus on the types of actions of the subjects and Ishii ^{5) 6)} focuses on the gazing points. Tatenami ⁷⁾, Hiroyoshi ⁸⁾ and Kato ⁹⁾ analyze the feelings of anxiety during route searches. Tatenami observes the changes in the degree of anxiety when PNS are used, but does not compare the results with those when using paper maps. Hiroyoshi applies protocol analysis to navigation while walking, but does not deal with PNS and focuses on how anxiety occurs. Kato also uses protocol analysis in his study, but focuses on wayfinding strategies in extraordinary route walking experiments. Before the experiments, he divided his subjects into two groups with a good or bad sense of direction according to their score on the Sense of Direction Questionnaire-Short Form (SDQ-S) and focused on how the subjects of each group made their way to the destination. The study scores the sense of direction, and does not attach importance to the state of mind when using different navigational tools. Hao Jiang ¹⁰⁾ apply protocol analysis to wayfinding to determine how newcomers and frequent visitors make decisions in complex multi-floor buildings. However, they do not focus on the state of mind but on the decision-making strategies. In contrast, the article by Hsuan Chang ¹¹⁾ is closer to our topic, comparing the use of mobile navigation systems and paper maps, and focusing on differences in mental state. However, the study analyzes the subjects' mental states via a questionnaire answered by subjects after completing all wayfinding tasks. Thus, the answers do not necessarily reflect the dynamic transition of their mental state corresponding to the situation of each location throughout the route. To fill the research gap, our research aims to clarify the difference in the types of anxiety between using PNS and using paper maps for ordinary route searches while walking to a destination. We focus on the ease of routes and various mental states such as anxiety and conviction, considering utilization tools by the use of protocol data and cognitive maps.

2. Research methodology

2-1. Outline of research method

To test the hypothesis that PNS, generally acknowledged for their convenience, could lead to kinds of anxiety in the mind of the user different from those induced by using paper maps, we analyzed how the state of mind while walking differs when using a PNS compared to that when

Figure 1: An image of the protocol analysis

using paper maps through actual subject experiments. According to the Oxford dictionary ¹²⁾, anxiety is the state of feeling nervous or worried that something bad is going to happen. Based on this, this research defines anxiety as the pedestrian's nervous or worried feelings about the tools and the external environment, including nervous and unpleasant feelings because it is difficult to divide above-mentioned feelings by using the protocol data. The experiments were planned to observe natural route searching behavior in an environment where elements other than the utilization tool are less likely to affect changes in the state of mind. Therefore, we set a time limit in an urban area where there are many passersby other than residents, and assumed the route search and route walking to a single destination as the simplest situation. Protocol analysis ^{8) 9) 13)} ¹⁴⁾ was applied to route searching while walking in each case of using a PNS and a map in order to analyze the difference in remarks until reaching the destination by comparison with the situation of the urban space. Austin and Delaney ¹⁴⁾ described protocol analysis as follows. "Protocol analysis is a set of methods for obtaining reliable information about what people are thinking while they work on a task. Although the term applies to a variety of methods for obtaining and analyzing verbal reports, we used concurrent verbal reports. With this method, rather than asking the subject questions as might be done in an interview situation, the experimenter simply asks the subject to 'think aloud' and verbalize his or her thoughts as if the subject were alone talking to him or herself." In other words, we recorded the subjects' monologues during experiments as shown in Fig. 1. At the end of the experiment, the subjects' verbalizations are transcribed into text from the tape recording. Analysis typically proceeds by segmenting the protocols into blocks of text. Considering the effect of the easiness of the route, the experiment used not only routes found in the Internet route search results but also routes with sharper twists and turns.

2-2. Outline of experiment

The target area of the experiment was around the South Exit of Shimokitazawa Station, Setagaya Ward of Tokyo as shown in Fig. 2. This area has an irregular and complicated street system, and there are no skyscrapers or high-rise buildings, which sometimes affect GPS seriously. From the station, we can see in sequence from the shopping district to the residential area ¹⁵⁾.

A New York Times article ¹⁶⁾ compares Shimokitazawa to Greenwich Village in New York city, an epicenter of youth culture in one of the trendiest metropolises in Asia. There are many shops

Figure 2: Images of Shimokitazawa

for young people such as vintage clothing stores, as well as live music clubs and cheap bars. This area originated as a farming village and has a long history as a residential area. After the Second World War, many people moved from the center of Tokyo to Shimokitazawa for its convenience and the cheap black markets and more people were attracted to live there in the 1980s for its shops, entertainment areas and proximity to the center. According to Hattori ¹⁷⁾, the lack of city planning restrictions at the time led to the development of narrow, winding streets with many cul-de-sacs. Andre Soares Lopes ¹⁸⁾ conducted experiments in Shimokitazawa district and found that landmarks, traffic signs, maps and visual permeability are the four main factors affecting wayfinding decisions. These articles and reports suggest that the area is suitable for the purpose of the current study.

An outline of the experiment is shown in Fig. 3. We conducted experiments on 25 students from Tokyo Metropolitan University in October 2017. Their average age was 21 years old, ranging from 18 to 23 years old; 48% of them were male and 52% were female. Some of the subjects had visited Shimokitazawa district to go to the shops and trendy bars, but nobody knew the place and the name of the destination of the experiment, Holy Trinity Church Tokyo. The reason that we chose this facility is as follows. First, the result can be applied to discussions on accessibility to public facilities. Second, this facility is a public church but has no signs along the routes to the facility from the station. Third, there is no large height difference from the station. Fourth, the routes are moderately difficult and arbitrary routes can be set. Last, visibility on arrival is high and the subjects can recognize that they have succeeded.

As shown by (1) of Fig. 3, in order to encourage subjects to utter a sufficient number of remarks, the think-aloud method was demonstrated to the subject and they practiced it while walking in the North exit district before the experiment. At the same time, the subjects practiced reading a paper map of the North exit district that has the same specifications as the one used during the

Figure 3: Outline of experiments

Figure 4: Images of the back gate (left) and the main gate (right) of the destination

experiment.

As shown by (2) of Fig. 3, the subjects were told that within 15 minutes from departure, they must get to the main gate of Holy Trinity Church Tokyo by following two routes. Both of the two routes have the same starting point at the south exit of Shimokitazawa Station, and the same destination at the main gate of the church. Route A is suggested by the route searching function of Google Maps and Route B is a simpler but longer route compared with Route A, as shown in Fig. 7. When we set Route B, we had to put a transit point around Point 20 due to the specification of the pedestrian navigation. Therefore, as the pedestrian approaches Point 20 when using PNS, the PNS is set to announce that they have arrived at the transit point. Regardless of the tool used, in the case of Route A, the tool does not display the position of the main gate of the church, shown on the left of Fig. 4, but displays the back gate, shown on the right of Fig. 4, and there are no signs indicating the position of the main gate even around the site.

As shown by (3) and (4) of Fig. 3, in order to avoid the influence of the order of using the tools, the subjects were randomly divided into two groups by the order of using the pedestrian navigation systems and paper maps. When using the PNS, the subjects obtained information on the route by themselves by using the Google Maps app on their smartphones. For Route A, the navigation information was given to the subjects directly by the route searching function of Google Maps. For Route B, the information had been saved in advance and was given via the Google Maps app. We saved Route A in advance in case the subjects could not find the route. On paper maps (210×297mm) printed from Google Maps website, we depicted Routes A and B in as much detail as possible.

The subjects carried a GPS loggers to record their tracks while walking, and their remarks were recorded by IC recorders with a tiny microphone attached around their necks. The subjects were prohibited from asking directions from passersby and they were watched by an observer who followed them from approximately 100 meters behind.

After the experiment, as shown by (5) of Fig. 3, each subject was requested to make a hand-drawn cognitive map in order to measure their space-recognition ability. The subjects were not told about this request before the experiments, in order to avoid them making efforts to remember the route. They were told to draw as many things as possible to guide others in following these two routes as well as the starting and destination points.

3. Experimental results analysis

Table 2: Experimental results

	Route A with Map	Route A with Navigation	Route B with Map	Route B with Navigation
Subject	13 students (*1)	12 students (*2)	12 students (*2)	13 students (*1)
Average duration time	15m04s ※Three persons couldn't arrive.	15m33s	13m42s ※One person couldn't arrive.	13m05s
Anxiety remarks	0.14	0.13	0.07	0.07
Conviction remarks	0.17	0.15	0.17	0.09

Table 2 summarizes the results of the experiment. Although four subjects did not reach the destination when using the paper map, by using the PNS everyone reached the destination. When using the PNS, in order to confirm the traveling direction in the vicinity of each node along the route, the action of checking the display of the current location icon by walking on the trail instead of checking against the surrounding environment was observed. In terms of duration, they took more time when using the PNS than when using the paper map in Route A. In total, the durations of Route B were shorter than those of Route A. One possible reason for this is that they obtained knowledge of the destination and that Route B is simpler than Route A.

In order to conduct protocol analysis, we classified all remarks into the eight groups shown in Table 3. As the method of classification, we adopted a modification of Hiroyuki's.⁸⁾ We divided the utterances into remarks by temporal boundaries and semantic boundaries, as well as by conjunctions in the case of long utterances. Even in a simple remark such as "OK," various states of mind such as anxiety, conviction, and self-persuasion may be combined. Thus, the remarks were classified into eight groups considering not only the meaning but also the voice tone at the time of recording. In addition, we utilized knowledge of the traits and speech habits of the subjects obtained in advance. The averages of the anxiety and conviction remarks are shown in Table 2. In order to calculate the average, firstly we calculated the share in the entire number of remarks by each subject in each experimental case, and secondly we calculated the average share throughout the same experimental cases.

3-1. Variance analysis

Figure 5 shows the shares of the numbers of remarks classified into eight groups for each route/tool. The numbers were used for the analysis of variance in order to verify the existence of difference by the route/tool and the results are shown in Table 3. The conviction remarks were greatly influenced by the tools, but the anxiety remarks were influenced by the difference of the routes, not by the tools.

The route difference affects the view remarks. One possible reason for this is that the proportion of the area occupied by shopping districts is higher in Route B than in Route A. The breakthrough remarks also differ greatly by the tool used. This is probably because the subjects stick to the current location icon on the screen when using the PNS, while they are actively trying to verify the surrounding environment when using paper maps, as reported by Hirai²⁾, Ishikawa⁴⁾ and Ishii⁶⁾.

Table 3: Remarks and results of variance analysis

Remark classification	Contents	Difference of tools	Difference of route	Reciprocal action
Anxiety	Remarks of anxiety "I am not sure whether this way is right."		***	
Conviction	Remarks of conviction "Because this spot is here on the navigation, I will turn at the next corner."	***	*	***
View	Remarks about the surrounding cityscape "That curry shop looks like it sells delicious curry."		***	
Situation	Remarks expressing own actions "OK.... I'm going to turn around as instructed."			
Positive	Remarks of self-encouragement "I can do it ! I'll make it ! "			
Breakthrough	Remarks expressing a breakthrough when lost or worries "Tentatively, let's go ahead!"	**		
Other	Remarks not related to the experiment at all "Can I finish my homework... ? "			
Time	Remarks concerning the time limit "I wonder if I will get there before the time limit."			*

Significant * : 10% / ** : 5% / *** : 1%

Figure 5: Remarks for each route and tool

3-2. Cognitive maps

In 1948, Tolman ¹⁹⁾ coined the term “cognitive map.” In 1973, Downs and Stea ²⁰⁾ defined cognitive map as “a series of psychological transformations by which an individual acquires, codes, stores, recalls and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment.”

In this research, the following instructions were given to the subjects in drawing cognitive maps. “For those who are visiting the church for the first time, draw a map assuming that you are telling them the route and include all the main features of the route. However, be sure to fill in Shimokitazawa Station as the departure place and the back and main gates of the church as the destination. A map sufficient for the next subject to get there is most desirable. If you cannot recall the intermediate part of the route, you may omit it with a pair of wavy lines. In addition, if you remember landmarks at the turning points such as stores, please draw them as well.”

The drawing environment was set according to the following criteria. The size of the paper was A4 (297 mm by 210 mm). No time limit was set, and correction could be made at any time. As reference information, the subjects could not look back on the tool. However, after the end of each walking experiment of Route A and Route B, the experimenter and the subject jointly walked the correct route back together, which might have given reference information. We never mentioned “cognitive mapping” even while walking back.

As cognitive operations involved in the process of drawing a handwritten map, in 1967, Beck and Wood ²⁰⁾ listed rotation, scaling, generalization, symbolization, verbalization, representation, and externalization.

In this research, in addition to the former five operations mentioned above, we analyzed lack of memory. As the elements of cognitive maps, Lynch (1960) and Murakoshi (1987) ¹⁹⁾ listed nodes as places, landmarks as visual features of places, paths as relations of places, and edges and districts as hierarchical relationships or inclusion relations. None of them considered lack of memory. With their evaluation methods, it is difficult to find lack of memory because they did not give the subjects the option of not drawing parts of cognitive maps due to their lack of memory. Our evaluation method compared with conventional evaluation methods is shown in Table 4.

The cognitive maps drawn by two of the subjects for Route A and the results of evaluation are shown in Fig. 6. The map in the upper part indicates a lack of memory, but the map in the lower part is completely correct in nodes and contains guidance information at each node, for example, “turn right here,” even though they were not requested to add this information. The cognitive maps of the routes drawn after the experiments by the subjects were evaluated according to the following four factors: 1) accuracy of nodes; 2) reference to landmarks near the nodes; 3) lack of memory; 4) guidance information. As for accuracy of nodes, we checked only the direction, i.e. Right, Left, Right, Left, Right, Left, Right, Left, Right, Right for Route A and Left, Right, Left, Left for Route B, without the length of path. We scored 1.0 for cognitive maps with no mistakes. Such maps include those where the travel direction of the next path is correct, such as turning right or going straight on, at all reproduced nodes, irrespective of the relative lengths of the paths and azimuth angles. We scored 0.5 for those with only one mistake and 0 for those with more mistakes. As for landmarks, we scored 1.0 for those with landmarks and 0 for those with no landmarks in the same way as above. In terms of lack of memory, when subjects draw cognitive maps with blank spaces, for example, as shown in the upper part of Fig. 6, these maps were scored 1.0. In contrast, when they drew maps with no blank spaces, for example, as shown in the lower part of Fig.6, these maps were scored 0. However, sometimes the subjects drew connections to the destination without blank spaces, so the accuracy of nodes is more reliable. With regards to guidance information, we also scored 1.0 for cognitive maps with guidance information, as shown in the red characters in the lower part of Fig. 6, and 0 for those with no guidance information.

Table 4: Our evaluation and related elements

This Research	Beck and Wood	Lynch and Murakoshi
1. Accuracy of nodes	Rotation Scaling	Path, Node
2. Reference to landmarks near the nodes	Generalization Symbolization	Landmark
3. Lack of memory	-	-
4. Guidance information	Verbalization	Edge, District

The average scores of the cognitive maps are shown in Table 5, which shows that the whole shape and topology of the routes were more accurate when using maps. However, the cognitive maps also show a tendency that the memory of the details of the routes, such as the length of links and the shops located between the nodes, becomes ambiguous when using maps. This result is different from that of Ishii⁵⁾. The results of this analysis seem inconsistent but could be interpreted as follows. When using paper maps, the subjects tried to find the nodes on the routes more than they did when using the PNS. Also, when using paper maps, the subjects could see the whole routes repeatedly. These factors might help the subjects in drawing the whole shape and topology of the routes more correctly when using paper maps than when using the PNS and might

Figure 6: Cognitive maps drawn by different persons in the same experimental type

Table 5: Average scores of the cognitive maps

Experiment type	Node	Landmark	Lack of Memory	Guidance information
Route A×Map	0.33	0.67	0.33	0.42
Route A×Navigation	0.25	0.67	0.17	0.42
Route B×Map	0.77	0.73	0.36	0.45
Route B×Navigation	0.58	0.85	0.23	0.38

make the subjects concentrate on the nodes but not on the items between the nodes.

In terms of the differences between the two routes, the subjects could draw a cognitive map more accurately when walking on Route B. This means that routes with Google Maps are not always easy to remember. In addition, regardless of the tool used, when there were few anxiety remarks, more nodes were drawn accurately.

In contrast, we analyzed the relationship between protocol data and cognitive maps by Spearman's rank-order correlation shown by the following formula:

$$\text{Spearman's rank - order correlation: } r_s = 1 - \frac{6 \sum_{i=1}^N (a_i - b_i)^2}{N(N^2 - 1)}, (1)$$

where a_i = (rank of variable A), b_i = (rank of variable B), N = (the number of samples).

We ranked their cognitive maps in order. As for the accuracy of nodes, we ranked maps that scored 1.0 as 1st, maps that scored 0.5 as 2nd and maps that scored 0 as 3rd. As for landmarks, we ranked maps that scored 1.0 as 1st and maps that scored 0 as 2nd. The same ranking process was

Table 6: Spearman's rank-order correlation coefficients

Route A×Map (n = 13)						Route A×Navigation (n = 12)					
Spearman's rank-order correlation: r						Spearman's rank-order correlation: r					
	Anxiety Remarks	Conviction Remarks	Accuracy of Nodes	Landmarks	Lack of Memory		Anxiety Remarks	Conviction Remarks	Accuracy of Nodes	Landmarks	Lack of Memory
Anxiety Remarks	1					Anxiety Remarks	1				
Conviction Remarks	0.02727	1				Conviction Remarks	-0.28671	1			
Accuracy of Nodes	0.02386	-0.52159	1			Accuracy of Nodes	0.20279	0.23076	1		
Landmarks	<u>0.6875**</u>	-0.18522	0.58181**	1		Landmarks	<u>-0.21328</u>	0.33216	0.46853	1	
Lack of Memory	<u>0.6875**</u>	-0.18522	0.58181**	—	1	Lack of Memory	<u>0.54195*</u>	0.12237	0.61538**	0.53846*	1
Route B×Map (n = 12)						Route B×Navigation (n = 13)					
Spearman's rank-order correlation: r						Spearman's rank-order correlation: r					
	Anxiety Remarks	Conviction Remarks	Accuracy of Nodes	Landmarks	Lack of Memory		Anxiety Remarks	Conviction Remarks	Accuracy of Nodes	Landmarks	Lack of Memory
Anxiety Remarks	1					Anxiety Remarks	1				
Conviction Remarks	0.31818	1				Conviction Remarks	0.45604	1			
Accuracy of Nodes	0.575*	0.67045**	1			Accuracy of Nodes	0.5934**	-0.0934	1		
Landmarks	0.6**	0.3	0.46818	1		Landmarks	0.33928	0.48214	0.44368	1	
Lack of Memory	0.15	-0.3	0.34318	0.6**	1	Lack of Memory	0.375	0.16071	0.7651***	0.42857	1

Significant * : 10% / ** : 5% / *** : 1%

applied to the lack of memory. We also ranked the subjects in order of the number of anxiety/conviction remarks in their protocol data, where the subject with the smallest number of anxiety/conviction remarks was ranked as 1st, the one with the second smallest number was ranked as 2nd and so on. Spearman's rank-order correlation coefficients among the remarks and evaluations of the cognitive maps are shown in Table 6. Generally, the correlation between the lack of memory and the accuracy of nodes is high. This means that subjects who concentrated on the path did not pay attention to nodes and vice versa.

As for Route A, the difference by utilization tools had the opposite effect on the correlation between conviction remarks and accuracy of nodes. At the same time, we observed an about 10 times wider difference between anxiety remarks and accuracy of nodes by difference of utilization tools. As mentioned before, Route A was the first experiment and the subjects did not know the destination at all. The result means that the PNS sometimes made the subjects feel anxious because it ended route guidance not at the main gate but at the back gate of the destination. This anxiety lead to the nodes of cognitive maps being drawn accurately, but this cannot be regarded as an advantage of the PNS. In addition, as shown by the underlined figures in Table 6, anxiety remarks were associated with landmarks and the lack of memory when using paper maps, but anxiety remarks were associated with only the lack of memory when using pedestrian navigation. Unlike the cases using maps, only the relationship between lack of memory and anxiety is strong in the cases using PNS. Therefore, it is inferred that subjects who become anxious when using PNS depend only on their own location icons. This suggests that, for some PNS users, the existence of landmarks has little significance in either navigation space or real space. This indicates that the level of interest in the external environment, including landmarks, differs between the map and the PNS, and that the usage of the two tools is different.

In the case of Route B, anxiety remarks were associated with landmarks and accuracy of nodes when using maps, but were associated only with the accuracy of nodes when using the PNS. The difference of utilization tools has a similar opposite effect on the correlation between the conviction remarks and the accuracy of nodes as in the case of Route A. One possible reason for this is that the subjects could check their current position with the PNS, but that the subjects could not check their current location with the paper maps. The result means that the PNS helps subjects memorize the routes, and it suggests that people who feel anxious drew cognitive maps more accurately just because the subjects had difficulties in wayfinding.

In summary, only when using maps, is the correlation between an anxiety remark and a landmark observed. One possible reason for that is as follows. The paper maps emphasize important landmarks and make it easier for pedestrians to identify their current location. However, PNSs do not prompt users to have an interest in the external environment including landmarks.

3-3. Remarks points by GIS software

Figure 7 and Table 7 show the results of plotting the anxiety remarks and the conviction remarks points by GIS for each route/tool using the tracks data and the remarks data. Buffers with a radius of 20 m from the points of nodes and landmarks such as a fire station were displayed regardless of the tool used, in order to count the number of remarks in each buffer. The anxiety and conviction remarks points differ depending on the tool used.

First, the reasons presumed at each point when using the PNS are as follows. At Point 7 on Route A, we observed not only many anxiety remarks but also conviction remarks at the same point.

There is a different church at this point and many subjects may have thought for an instant that this church was the destination. This inference could explain why the number of anxiety remarks and the number of conviction remarks were both large at the same point.

At Point 11 on Route A, the subjects felt anxious. This point looks a like dead end and has no prospect in Fig. 8 but when going forward the end of the route appears. This visual structure of the point might have made the subjects gain confidence in the set route and increased their confidence remarks.

The subjects showed unique action with using the PNS at Points 14, 15 and 16 near the back gate of the church in Fig. 4. More anxiety remarks were made around there than when using PNS than when using paper maps perhaps because the PNS finished guidance and announced that it was the destination. However, they had only found the back gate, which looked locked and private, and the cross in the sky but they had not found signs of the main gate. There is also a narrow alley at right angles to the destination, which cannot be found easily.

Next, the possible reasons at each point when using the paper map are as follows. The reason why more conviction remarks were observed, when using the paper map than when using the pedestrian navigation, at Point 0 near the starting point, might be the existence of McDonald's located as a large street-side shop near the starting point and indicated on the paper maps. By its

Table 7: Number of remarks at each buffer point

Point		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Paper Map	Anxiety	32	12	2	7	11	6	4	3	2	7	2	7	4	1	2	9	11	1	2	3	15	5	11
	Conviction	52	7	18	9	4	5	7	16	8	13	7	3	11	14	10	13	5	8	3	4	13	8	9
Pedestrian	Anxiety	25	2	1	16	3	2	3	25	6	6	2	17	9	2	20	30	14	1	3	2	11	4	3
Navigation	Conviction	26	1	7	9	4	5	3	20	8	8	6	6	5	10	18	23	7	11	6	12	14	3	5

Figure 7: Route map and remarks (shown by blue points)

Figure 8: Images of Point 11 (left) and Point 12 (right)

existence the subjects could confirm the consistency of the map against the surrounding environment. The reason why the number of the anxiety remarks is large at Point 20 on Route B might be that a division road appears all of sudden. Although the name of the node is printed on the paper maps, it is rather difficult to confirm the location on the site. A signboard is provided on the traffic signal, but it is installed on a diagonal line, a difficult place to find. The route proceeds from a road with a lot of traffic to a residential area in a narrow alley, which can also cause anxiety.

4. Conclusions

This research found that the use of PNS on smartphones when route searching while walking did not reduce anxiety as expected. The results show that the difference in the ratio of the number of anxious remarks when using the tools was not large. This suggests that the hypothesis of this research, "pedestrian navigation systems, which are usually considered to be convenient, may raise different types of anxiety in the user's mind from paper maps" is reasonable. The results suggest that the use of PNS does not necessarily induce less anxiety than the use of paper maps. The points about which we feel anxious differ according to the tool used. Some subjects believe or stick to the current location icon on screen when using the PNS and this causes anxiety when landmarks cannot be found. In addition, subjects can draw cognitive maps of the route they have taken more accurately when using paper maps. The result that the types of anxiety among tools are different suggests several points to be improved for pedestrian navigation as a tool that can substitute maps. Because of the tendency of anxiety being caused in some people who ignore reference to the external environment using PNS, using VR technology to match the direction of the navigation image and the real image seen by users can be effective in facilitating the users' reference to the external environment. An example of a similar technology proposed by Google was described in an article in The Wall Street Journal.²¹⁾

Future study is necessary concerning comparison with orthogonal grid areas such as those in New York city or Marunouchi district in Tokyo and that with actions, asking for directions, and the application of eye mark recorders to conduct experiments for precise performance of protocol analysis, and the scale of anxiety should be evaluated. This research identified the anxiety of subjects via their protocol data but with using no scale. By measuring their physical condition such as their heartbeat, we might measure their anxiety according to a scale. It will also be beneficial to compare the results of this research with those of subjects who are not familiar with pedestrian navigation on smartphones like seniors because all the subjects of this experiment were

young university students who are skilled with the use of PNS on smartphones. This will be useful for obtaining knowledge that can contribute to the universal design of digital devices.

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