Study on the Effect of Spatial Cognition Methods on Indoor Emergency Evacuation

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Abstract

In building fire emergencies, way-finding capabilities can affect people's evacuation efficiency and chances of survival. The purpose of this paper is to explore the influence of spatial cognitive methods on people's way-finding ability. In this research, we used VR technology to conduct experiments. In an immersive virtual environment, 64 participants were asked to actively explore virtual malls by using YAH navigation and paper maps to find destinations and complete buying tasks, respectively. After that, 32 participants needed to alienate the virtual mall with a time limit, while the else had to complete the same task without a time limit. In the experiment, the participants were exposed to the environment for the first time and were unfamiliar with it. The results showed that participants using paper maps walked longer (710 m vs 932 m) and took more time (666 s vs 922 s) to complete tasks of evacuating the mall than those who used YAH navigation maps. The findings also showed that participants spent more time (521 s vs 790 s) looking for exits under time constraints and found evacuation tasks more difficult. This article discusses the mechanisms of these findings.

Introduction

Fire is a serious disaster in interior buildings. According to the data of the National Fire Authority, in the first quarter of 2021, a total of 389.77 people died due to building fires (<https://www.119.gov.cn/article/3xBeBylHerh>). In an indoor fire, the efficiency of evacuation and the chances of survival are greatly affected by the way-finding⁶⁶. Way-finding is a process of people looking for a destination along path²⁸. In essence, it is an action of cognition and problem solving, which consists of cognitive processes such as reading a map, remembering the route, finding the position and maintaining the direction through external features or landmarks⁹⁻¹⁸.

Self-orientation and spatial orientation are two key processes in way-finding. However, with the development of the commercial economy, the tendency to be complicated of the internal structure of buildings not only increases the cognitive burden but also makes it difficult for people to find their way². People's spatial knowledge of an unfamiliar environment of buildings comes from their cognition of spatial information such as landmarks, routes, and the whole in the environment⁴⁹. Spatial knowledge is stored in people's mental representation of space, known as cognitive maps²³. In the process of way-finding, people extract spatial knowledge through cognitive maps¹⁹ and formulate reasonable way-finding strategies to guide way-finding behaviors⁵⁰⁻⁵¹. The ability to find ways depends on people's use of route knowledge or overall knowledge².

Maps are a major tool for people to obtain spatial information in an unfamiliar built environment⁴², which is beneficial for people to form cognitive maps covering the overall spatial information⁵. In the process of map navigation, people can obtain spatial geographic information about the entire environment from the map and carry out self-positioning and spatial orientation by combining the mapping between the text interface and environmental graphics⁶⁵. Although paper maps can provide participants with complete

spatial geographic information, they also increase the cognitive burden of users, who need to quickly identify spatial information, plan the path and reach the destination within a limited time⁴⁸.

With the development of modern technology, a large amount of spatial geographic information is transmitted electronically through mobile phones and the Internet^{75,5}. People who can place themselves in the physical space and space are shown in the map symbol matching, real-time position their position in space^{30,68}, and obtain more spatial information in a short time^{78,4} for spatial orientation and routes finding^{11,32}. Compared with traditional paper maps, electronic maps have the advantage of quantitative judgment and can better communicate landmarks and route knowledge to users. However, some researchers have proposed that the use of electronic navigation is not good for people to acquire spatial knowledge about the environment^{24,25,42}. Moreover, compared with more traditional way-finding methods such as paper maps, technology-assisted way-finding will hinder people's acquisition of spatial knowledge^{18,41,42,44,46}.

Because of its real-time and interactive characteristics, electronic maps have been widely used in life. However, as a carrier of information describing human life, paper maps still play an important role in people's way-finding process, which is the priority for people to find their way²². Therefore, it is necessary to compare paper maps and electronic maps in modern society. Previous studies on paper maps and electronic maps mainly focus on outdoor way-finding and exploratory research^{5,6}. For example, research on the application of paper maps in modern digital mapping society²²; research on indoor navigation using augmented reality⁴ etc., while there are few studies on people using maps for indoor way-finding. Second, in previous studies, paper maps and various electronic maps are mainly used in way-finding behavior under normal circumstances, such as different studies of augmented reality (AR) and binary navigation electronic maps in people's way-finding behavior¹⁵. The influence of different information formats and spatial cognition on individual way-finding performance². There is a lack of research on the design of indoor navigation interfaces compatible with human information processing in emergency situations, such as emergency evacuation⁶¹. Finally, when people are under great psychological pressure, which type of map is more efficient for evacuation is also a question worth exploring.

To understand indoor way-finding behavior efficiently and accurately, researchers have used various methods, such as questionnaires¹², posture estimation⁶⁰, and real-time tracking methods²⁹. However, these experimental methods have some limitations. First, they lack overall experience with the environment. Second, they are expensive. Third, it is difficult for people to collect data and set up a controlled experimental environment. In recent years, virtual reality (VR) has been widely used in the research of human navigation and way-finding behavior^{6,30,70} and is a "real or simulated environment that the perceive experiences remotely"⁵³. VR (virtual reality) can provide a highly realistic virtual environment (IVE) to evoke participants' psychological and behavioral responses to a simulated environment with high ecological validity^{30,61}. The immersive virtual environment (IVE), as a new

experimental method,provides a feasible alternative for indoor way-finding behavior research.Using an IVE-based approach,our goal is to examine two questions:

First,how do different ways of spatial cognition in indoor environments affect people's ability to find exist?

Second,how does stress in fire evacuation interact with spatial cognitive patterns to affect people's ability to escape fire emergencies?

Methods

Participants

In total,64 participants with normal vision or correction,no color blindness or other eye diseases were included in our research,and 32 participants were men,the other participants were women.They were randomly divided into 4 groups of 16 people,equally male and female.The experimental groups as shown in Table 2.The participants in the included articles had a mean age of 22–23 years and an equal percentage of men and women.Each participant received 50 CNY for their participation.The participants were informed that they could quit the experiment at any time and were asked to sign an informed consent form before the experiment began.The study was approved by the Ethics Committee of Sichuan Normal University and all experimental procedures were performed in accordance with the Declaration of Helsinki.

Experimental equipment

To compare the different influences of modern navigation systems and traditional paper maps on emergency evacuation behavior in indoor fires,we selected one of the common navigation methods in VR,the YAH navigation map,which can be marked in real time for participant spatial locations that can be experimented with,and a traditional paper map to experiment.

Experimental environment scenario

In April 2021,a major fire in a commercial square in Anhui Province resulted in four deaths. In this experiment,we selected it as the script and took a medium-sized shopping mall as the experimental scene.Before the fire in the mall,the milk tea shop is launching a new ice cream.To eat the ice cream,everyone crowded in front of the milk tea shop to wait.In the experiment,all participants needed to arrive from the same mall entrance to buy ice cream at the milk cream store selling ice cream.

Experimental scene

The IVE used in this study is the first floor of a large virtual shopping mall,50 meters long, 40 meters wide,and 4 meters high.As seen in Fig. 1,there are 15 east-west stores in the mall,and a comprehensive

mall is distributed in the center of the mall,including jewelry, clothing and other shops. Milk tea shop, route, and fire point have been replaced by small red flag, color line, and five-pointed star, respectively.

The mall has designed 4 conventional entrances and exits and five evacuation routes, as shown in Fig. 2. Furthermore, the participants did not walk through the walls across the IVE. As shown in a pentagram symbol in Fig. 1, there is 1 fire site for emergency fire experiment conditions. Flames at the fire point can spread to 3 m*4 m and smoke to a considerable area to ensure that they can be seen anywhere in the mall (Fig. 3).

Experimental design

In this experiment, participants were divided into four groups, two of which needed to experiment by using paper maps, while the other two groups were required under the guidance of the YAH navigation map. In the experiment, the participants needed to complete the buying and evacuation tasks. As shown in Table 2.

During the buying task, participants in the paper map and YAH navigation map groups needed to arrive at the milk tea shop at normal walking speed (1.2 m/s) to buy ice cream. Participants in the YAH navigation map group needed to set 5 coupons in the designated shop in turn using the following routes: from the entrance, successively through the bookstore, dining area, lounge, department store area, and clothing store to the makeup shop. After the participants arrived at the milk tea shop, fires suddenly occurred, and the participants were required to perform the evacuation task and leave the mall as soon as possible. For evacuation tasks, we used the design between participants in 2 (spatial cognition mode: paper maps and YAH navigation maps)*2 (experimental condition: time limit and no time limit). Before the experiment, the experimenter needed to calculate the average time when the participants of the paper and YAH navigation map groups evacuated without the evacuation time limit (according to previous studies, we assumed that the evacuation time obeys the normal distribution) and calculate the limited evacuation time (the mean reduces a standard difference) as the time limit condition of the experiment. Participants in the other two papers and YAH navigation maps were evacuated under experimental time constraints.

The entire experiment lasted approximately 4 minutes-5 minutes to ensure that the participants could complete the experimental task. During the experiment, the participants used their own navigation aids to find the way, and they all participated for the first time and were unfamiliar with the experimental scene. The five evacuation routes designed in the experiment are as follows: route 1 is 40 m; route 2 is 30 m, which is the shortest evacuation route; route 3 is 60 m, which is the longest evacuation route; route 4 is 42 m; and route 5 is 50 m. As seen in Fig. 2.

Experimental procedure

The main experimental procedure of this study are summarized in Table 1. Participants arrive at the laboratory to sign the consent form and fill in the basic personal information: age, gender, occupation and so on. Then, participants were required to fill in the PANAS mood scale, enter the corresponding room

showing the simple virtual environment, be familiar with the use of navigation map, operate the lever and complete the relevant tasks in the virtual environment.

Then, the experiment officially began. In the first stage, the participants of the map group freely explored the mall and arrived at the milk tea store; the YAH map group visited the designated store under the guidance of navigation to accumulate the discount coupons in proper order. The differences between the paper map group and the YAH navigation map group participants are that the paper map group participants have greater degrees of freedom in the route decisions.

In the experiment, the experimenter needed to calculate the average time when the participants of the paper and YAH navigation map groups evacuated without the evacuation time limit and calculate the limited evacuation time as the time limit condition of the experiment. Then, participants in the other two teams of paper and YAH navigation maps were evacuated under experimental time constraints. Upon arriving at the milk tea shop, a sign saying "you've arrived at your destination, please leave the mall as soon as possible (within 33 seconds)" appeared in front of the participants. Both virtual flames and smoke occur simultaneously.

After the experiment, participants completed the PANAS mood scale again to test the participants' psychological stress before and after the trial, as shown in Table 1. Participants will then need to answer the following questions:

- (1) Rating the use of maps and navigation;
- (2) Scores the difficulty of way-finding and evacuation;
- (3) Evaluates the vividness of virtual shopping malls.

Data analysis

way-finding behavior analysis

In this study, we collected six measurements to assess the performance, mainly their walking time, walking distance and route selection in the buying and evacuation tasks. The main findings of these data are summarized in the following Tables 3, 4, 5, 6, 7, 8:

First, we analyzed the walking time and walking distance of buying tasks 2 (spatial cognitive method: paper map group or YAH navigation map group) and 2 (experimental conditions: time limit and no time limit) between the participants. The results showed that there were no significant differences in spatial cognitive patterns in terms of walking distance of the buying task: ($F(1,30) = 0.009156, P = 0.924404, F_{crit} = 4.170877$), as shown in Fig. 4. From the point of view of walking time, the difference of spatial cognition mode will not cause significant difference ($F(1,30) = 3.050157, P = 0.090963, F_{crit} = 4.170877$). These results show that participants who use YAH navigation maps are not very different from

those who use paper maps in the distance and time spent buying tasks. The difference between sex and walking distance and time was also not significant ($P = 0.5 > 0.05$; $P = 0.509017 > 0.05$).

At the same time, the variance analysis of 2 (spatial cognition: paper map group or YAH navigation map group) * 2 (experimental conditions: time limit and no time limit) shows that different spatial cognitive patterns have a significant effect on the distance of evacuation: ($F(1,30) = 6.595162, p = 0.015448, F_{crit} = 4.170877$), and the differences in spatial cognition can also have a significant impact on the time of evacuation in terms of evacuation time ($F(1,30) = 7.52434, p = 0.01017, F_{crit} = 4.170877$), as shown in Fig. 5. These results show that participants who used paper maps traveled longer distances (710 m vs 932 m) and took more time (666 s vs 922 s) than participants who used YAH navigation maps, as shown in Fig. 4. The difference between sex and evacuation distance and time was not significant ($P = 0.52314 > 0.05$; $P = 0.382004 > 0.05$).

Finally, the experimental results also show that there is no interaction between gender and spatial cognition; that is, there is no interaction between gender and spatial cognition on the walking time and distance of snatching and evacuation tasks.

We also performed an ANOVA with 2 (spatial cognition mode: paper map or YAH navigation map) * 2 (experimental conditions: time limit and no time limit) * 2 (evacuation behavior: time or distance). We investigated whether different spatial cognitive approaches and experimental conditions interacted with evacuation time. The results showed that different spatial cognition and experimental conditions interact with evacuation time and under evacuation time limit, in contrast to the participants in the YAH navigation map, participants using paper maps were evacuated at longer distances ($F(1,30) = 13.66, p = 0.00087, F_{crit} = 4.1701$), (523 m vs 727 m), and more time ($F(1,30) = 12.067, p = 0.00158, F_{crit} = 4.171$), (521 s vs 790 s), as shown in Fig. 5.

To test for differences in sex in experiments, we performed ANOVA on 2 (spatial cognitive mode: paper or YAH navigation maps) * 2 (experimental conditions: time limit and no time limit) * 2 (gender: male or female). Experimental results showed that neither the main effect of sex nor the interaction effect between sex and other independent variables were significant.

Results

The focus of this experimental study is the spatial cognitive efficiency of participants under different spatial cognitive modalities and therefore a comparative analysis between spatial cognitive efficiencies under different spatial cognitive modalities. Participants shared spatial cognition in two categories (paper maps and YAH navigation maps). First, in the analysis of path selection for participants, as shown in Fig. 6 below, path selection varies greatly between groups and spatial cognitive methods, and path selection varies significantly. In normal evacuation tasks, 4 participants (25%) chose the shortest path 2 using the paper map, while 8 participants (50%) chose path 2 using the YAH navigation map. With the evacuation time limit, 3 participants (19%) using the paper map selected the shortest path 2, while 12 participants (75%) using the YAH navigation map selected path 2, as shown in Fig. 6:

In the experimental scenario of this paper, we designed the shortest path, route 2. We analyzed in our experiments that the percentage of participants using the YAH navigation maps who correctly selected the shortest route was 63% compared to participants using paper maps. Experimental results showed that participants using YAH navigation maps had more spatial cognition than those using paper maps, namely, that YAH navigation maps were more favorable to participants' access to spatial knowledge.

Subjective evacuation and analysis

We summarized all the subjective evaluations of the participants. First, we performed a mixed design ANOVA of 2 (experimental stage: before or after experiment) * 2 (experimental conditions: time limit and no time limit), which was an internal factor and experimental condition between subjects. The results showed significant differences in fear ratings before and after the experiment. Participants with the evacuation time limit felt more afraid after the experiment than before the experiment, while participants without the evacuation time limit group did not differ greatly in mood changes before and after the experiment. These results suggest that participants did change in psychological pressure with evacuation time limits compared to the no time limit group. We also performed a mixed design ANOVA of 2 (experimental conditions: time limit and no time limit) * 2 (gender: male or female). Experimental results showed that female participants were more prone to changes in psychological stress than male participants.

Based on this basis, we also estimated an ANOVA of the difficulty of buying task and evacuation task 2 (spatial cognitive mode: paper or YAH navigation map group) * 2 (experimental condition: time limit and no time limit), which showed that different spatial cognitive methods significantly affected the difficulty, which participants using paper maps considered harder to complete than participants using the YAH navigation map. The results also showed that for the difficulty evaluation of the evacuation task, the difference in experimental conditions had significant effects and that participants with an evacuation time limit than no evacuation time limit participants considered a successful evacuation task harder. No other major or interaction effects were significant.

Finally, this paper was also tested for independence for each of the following confounders, including the degree of participants' familiarity with the VR environment and the vividness of the virtual environment.

Discussion

The main findings and effects of this study are summarized in Table 9. This section discusses these findings in further detail.

Effect of different spatial cognition methods on evacuation behavior.

In conclusion, the results of this study show that the participants of paper map groups walk for a long distance and time during buying tasks. YAH navigation maps can save subject cognitive

resources⁶⁴. Participants using paper maps require intensive, complex spatial knowledge acquisition and processing processes. This is consistent with the conclusions of Kruger and Munzer, where mobile navigation techniques better communicate landmarks and routes to users for route finding compared to traditional maps. In addition, during the experiment, the YAH navigation map group tried to follow the planned route of navigation, so it was shorter than the average length of the route of the paper map group. This is demonstrated by a review of the experimental video, with a detour or return of 19% (6 of 32) in the paper maps, causing them to spend more time on the longer route completing the buying task.

The results also show that the paper map group participants walked longer in the evacuation task than the YAH navigation map group participants and considered the task more difficult. The main reason for this difference between the two groups of participants is as follows: first, the goal of the evacuation task. The goal in this study is to find the mall exit. In the evacuation task, the participants do not need a complete space cognitive map, and the space knowledge related to the exit location is sufficient to help participants find the exit of the mall. Cao Li jun and others also found that participants with some spatial knowledge tended to evacuate through the routes they were familiar with. Second, participants exploring the space along the route specified in the YAH navigation map do not need to compare the spatial representation on the map with the environment to find the specified location. They can follow the real-time guidance of the navigation map and maintain a relatively stable forward direction, the direction of the exit. Finally, in the experimental process, the paper map group participants may go in the wrong direction, circle or return behavior, causing confusion regarding spatial cognition. In summary, in the case of indoor fire bursts, the YAH navigation map is more conducive to guiding people's emergency evacuation behavior.

Effect of the experimental conditions with evacuation restrictions on the evacuation behavior

The results of this experiment also show that the participants spent more time searching out the mall exit and considered the evacuation task more difficult. These results are consistent with those of Cao Li jun (2019), etc., where participants in fire emergency conditions escape longer than participants finding exits in normal conditions. These findings indicated that the evacuation time limits had important effects on the participants' evacuation performance during the evacuation task. First, the participants produced a stress psychological response to fire incidents and felt more scared after the experiment than before the experiment^{66,47}. People in fire emergencies have greater physical and psychological stress, different perception patterns, different behavior patterns, and poor road-finding ability⁴⁵.

Proulx's pressure model (1993) also shows that people will feel fear or stress in the face of a sudden fire. In this paper, we control people's psychological stress by controlling evacuation time and find that participants have greater psychological pressure in the time limit compared to participants in the no time-limited group. There was a significant increase in pressure in the time-limited compared to participants in the no time-limited group. A significant increase in pressure creates a high pressure state that limits people's ability to deal with environmental information effectively⁴⁵ and leads to a decrease in evacuation efficiency.

Meanwhile, the results also showed that there was no significant difference in the walking distance of the successful evacuation. This suggests that although the presence of evacuation time limits can affect the subject's ability to perceive and process environmental information, these restrictions do not affect their ultimate success in finding the right route to the exit.

Finally, we find that the experimental conditions with evacuation time limit have no significant effect on the vividness of the virtual environment and the participants' familiarity with the virtual environment. Therefore, it can be shown that the differences in the trial times in this study were not caused by individual differences.

Effect of different spatial cognition methods on the spatial cognition efficiency

Participants in paper map groups varied significantly in the choice of paths. Using paper maps, 7 people selected path 2 (22%); the YAH navigation map group subjects also differed significantly in path selection, with 20 people selected path 2 (63%). In this paper, we control for factors such as gender, population density and spatial cognition within the two groups and consider only the different route selection between groups. Experimental results show that the YAH navigation maps choose the shortest route (22% vs 63%) compared with the participants in paper maps, namely, the YAH navigation map is more conducive to obtaining spatial knowledge about the environment and improving people's spatial cognitive efficiency of the environment. This is inconsistent with the results of Golledge and Aslan that technology-assisted routing reduces spatial knowledge gained compared to more traditional path-finding methods such as using paper maps.

Limitations

There are some limitations in the study of this paper, which can be corrected in future research. First, the experiment only considered the impact of two spatial cognitive methods on people's ability to explore roads in fire. Due to the lack of research on other spatial cognitive methods, other spatial cognitive methods can be studied in the future. Second, the number of participants is limited, so the results are not very representative; expanding and including human age and expertise will be a good choice in the future. Finally, way-finding is a complex cognitive process, and each of these steps may be affected by spatial cognitive methods and fire emergencies. In the future, it will be possible to study the influence of dynamic changes in fire on way-finding behavior.

Conclusion

Our study demonstrated several conclusions. First, the YAH navigation map is more beneficial to guide the behavior of emergency evacuation. Second, the YAH navigation mapping group is more conducive to obtaining spatial knowledge about the environment and improving people's spatial cognition efficiency of the environment. Finally, psychological stress will limit people's ability to effectively process environmental information and reduce evacuation efficiency.

Declarations

Data availability

The data and material of the current study will be available from the corresponding author upon reasonable request.

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Tables

Table 1 Experimental procedure

Table 2 The Experimental groups

Table 3
The waking distance of different spatial
cognition methods under normal condition

Paper Map (Buying)	YAH (Buying)	Paper map (Evacuation)	YAH (Evacuation)
141	110	101	61
130	100	87	57
124	99	78	50
118	98	70	49
112	97	67	49
99	93	62	48
96	92	59	46
89	92	54	43
78	91	52	43
76	91	52	42
73	89	49	41
72	89	47	40
70	88	39	38
69	87	36	36
69	79	35	36
68	79	35	31

Table 4
The waking time of different spatial cognition
methods under normal condition

Paper map (Buying)	YAH (Buying)	Paper map (Evacuation)	YAH (Evacuation)
260	160	97	70
217	152	89	50
203	130	89	49
169	126	75	46
161	121	68	46
159	121	61	43
150	119	60	43
148	118	53	42
134	117	51	39
108	116	51	39
101	115	51	38
97	110	40	38
95	110	39	36
95	101	36	29
92	98	32	29
88	81	30	29

Table 5
The waking distance of different spatial cognition methods
under time-limit

Paper map(Buying)	YAH (Buying)	Paper map(Evacuation)	YAH(Evacuation)
99	91	50	29
101	87	72	31
97	92	34	28
78	89	32	27
74	88	42	30
67	89	62	29
109	93	42	39
132	87	41	32
79	86	42	26
116	85	51	41
132	86	52	27
95	90	31	28
87	91	61	42
124	88	41	30
96	87	43	51
89	86	31	33

Table 6
The waking time of different spatial cognition
methods under time-limit

Paper map (Buying)	YAH (Buying)	Paper map (Evacuation)	YAH (Evacuation)
178	108	41	30
210	110	92	26
143	101	38	24
121	99	40	22
101	103	49	26
97	110	71	30
189	116	39	41
201	102	43	27
110	94	41	21
154	104	60	40
178	99	61	31
118	131	35	27
108	101	56	50
189	134	39	29
103	109	45	67
99	107	40	30

Table 7
The waking time and distance of different spatial cognition
methods under normal condition

YAH	Sum	Average	Standard deviation
Buying distance	1474	92.125	16.13225
Buying time	1895	118.4375	32.69395
Evacuation distance	710	44.375	13.27849
Evacuation time	666	41.625	16.22417
Paper map	Sum	Average	Standard deviation
Buying distance	1484	92.75	18.308
Buying time	2277	142.3125	39.53689
Evacuation distance	932	57.6875	15.76153
Evacuation time	922	57.625	18.05029

Table 8
The waking time and distance of different spatial cognition
methods under time-limit condition

YAH map	Sum	Average	Standard deviation
Buying distance	1415	88.44	2.39
Buying time	1728	108	10.99
Evacuation distance	523	32.69	6.97
Evacuation time	521	32.56	11.88
Paper map	Sum	Average	Standard deviation
Buying distance	1575	98.44	28.84
Buying time	2299	143.69	41.22
Evacuation distance	727	45.44	11.91
Evacuation time	790	49.38	15.28

Table 9 The main findings and effects of this study

Independent variable	Dependent variable	result
Spatial cognition: A paper map or YAH navigation map	The walking time of the buying task	No significant difference
	The walking distance of the buying task	No significant difference
	Assessment of the difficulty of buying tasks	Paper map > YAH map
	Evaluation of the difficulty of using paper maps	Paper map > YAH map
	YAH navigation maps use difficulty assessments	Paper map > YAH map
	Percentage of shortest path selection for paper maps	22%
	Percentage of shortest path selection for YAH maps	63%
Experimental conditions: No evacuation time limit or evacuation time limit	The walking distance of the evacuation task	Paper map > YAH map
	The walking time of the evacuation task	normal > time-limit
Experimental stage: Before or after an experiment	The difficulty of the evacuation task	time-limit > normal
	Nervousness	Before > after
	fear	Before > after

Figures

Figure 1

Illustration of the structure of the mall

Figure 2

Five evacuation routes

Figure 3

Pictures of fire and smoke

Figure 4

The waking distance and walking time of different spatial cognition methods

Figure 5

Walking distance and time of different experimental conditions

Figure 6

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