

Follow the evacuation signs or surrounding people during building evacuation, an experimental study

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ABSTRACT Evacuation signage plays a vital role in building evacuation. In order to test the efficiency of evacuation signage, the traditional methods are video analysis and after-drill questionnaires and the human factors are rarely considered. This paper investigates the impact of surrounding pedestrians on the sign guidance efficiency during building emergency evacuation, replacing the traditional ways with eye tracking device method. More than 500 participants were involved in the series of experiments to test the influence of surrounding people on detecting and following signages. It is found that a) the subjective ignorance and objective ignorance of signs exist obviously and are affected by surrounding people number; b) strangers and acquaintances have similar effect on the sign detection probability and direction choosing probability in the safe and quick evacuation experiments, contrary to general belief; c) One surrounding person has an important influence on the sign guidance effect, especially on the following probability, while three surrounding people not. Based on the results of the experiments, a new logic of wayfinding within rooms was put forward and simulated to compared with the original logic. It is shown that the average right direction choosing percentage decreases by 30% after considering the effect of surrounding pedestrians, proving that the impact of surrounding pedestrians must be considered in evacuation modeling and evacuation route design.

INDEX TERMS Pedestrian evacuation, Wayfinding, Evacuation signage, Surrounding pedestrians, Eye tracking device.

1. INTRODUCTION

A. BACKGROUND

With the development of society, there are more and more complex indoor buildings in the cities, such as malls, theaters, and airports. Normally, many turnings and obstacles are involved in the evacuation routes within the buildings. It will be quite difficult to escape for the consumers without guidance. As a result, many countries have building regulations and guidelines about evacuation guide signs [1]-[3]. According to ergonomics, studying the interaction between evacuation signs and evacuees can make useful contributions to understanding the human behavior in emergencies and building evacuation sign design, which will promote the efficiency of emergency evacuation [4]-[6].

As evacuation signs are the most important information indicators for indoor evacuation, pedestrians interact with the signs and make the evacuation decision after processing the signals [7], [8]. In the emergency evacuation, a successful evacuation signage system will reduce the wayfinding time and decrease the building complexity, while a poor system may

lead to more congestion or wrong route choices resulting in evacuation delay [8]-[11].

B. LITERATURE REVIEW

Due to the significance of evacuation signs, many researchers have paid much attention in recent years. The research mainly focuses on 3 parts, a) the effect of various evacuation signs, b) the effect of different intelligent evacuation guidance system and c) the evacuation signs in special places.

The sign effect research concentrates on the single sign design and position to make the signs easier to detect and read. The two main research methods are from real experiments and virtual reality experiments. And they are often combined with questionnaires. For real experiments, Fu et al. designed a building evacuation route involved several corners to test different arrow graphic guidance effect, considering the detection probability and following probability [12]. The route choice and sign effect are collected by the experiment videos and questionnaires. Galea et al. made extensive questionnaires internationally to verify the detecting effect of different negative marks on the traditional green evacuation signs [13], [14]. After that, they conducted an experiment in a subway station to confirm the effectiveness of dynamic signage system.

Olander et al. made a survey about the sign colors, graphics and twinkling or not and analyzed the data with Theory of Affordance [15]. Xie et al. asked the experiment staffs to pass the zones quickly to test the effectiveness and analyzed the guiding effect through the videos and questionnaires [16]. Kwee-Meier et al. studied the flashing sign effect difference on young participants and old ones to study the influence of ages [17].

On the other hand, virtual reality technology is imported to verify the evacuation sign effect. Arias et al. manufactured a virtual environment of CERN and compared the pedestrian detecting and follow choices under the red flashing signs, dynamic signs and robot information guidance [18]. Tang et al. constructed an experiment space with virtual reality and simulated three scenarios, without signages, with old-version signages and with new-version signages [11]. After the experiments, the average way-finding time and gender effect are compared. Kinatader et al. immersed the experiment participants in a virtual room with two exits and contrasted the effect under different sign colors [19]. It is found that the behavior differs from the verbal report. Cai et al. studied the feasibility of mixed reality equipment HoloLens in the research on evacuation signs [20].

The evacuation guidance system research aims to develop a more intelligent and effective system in complicated buildings and promote the smooth evacuation. Lee et al. combined the IoT system and digital evacuation signage system to conduct a GUIDE system [21]. It collects the IoT information to distinguish the safe zones and dangerous zones in the buildings and then displays the best evacuation route with signages. The guide system decreases the probability of wrong direction occurring. Yenumula et al. developed a similar indoor evacuation intelligent guidance system but based on BIM system [22]. As to the sign effect simulation, Zhang et al. developed a cellular automaton model to simulate the sign effect considering the perceiving and deciding probability and put forward a piecewise function to calculate the effectivity of evacuation signage system [23]. It is used to optimize the sign locations in the public space. Langner et al. established an agent-base model to simulate the signage system in a local football stadium [24]. The results show that the dynamic signage can speed up evacuation and reduce fatalities. Cisek and Kapalka developed an active and dynamic evacuation model [25]. The model contains an algorithm for determining all possible evacuations plans and then chooses the best route to present with active dynamic evacuation signage system.

As to a few special places, there are some unique demands on evacuation signs and guidance systems. Some researchers have done much contribution. Kwee-Meier et al. conducted an experimental study on digital emergency signage in a ship [26]. During the drills, different stress levels are involved to simulate the ship evacuation. It is indicated that digital escape route signage system distinctly can prevent merging and crossing passenger streams and thereby enhance safety. Mandel and Johnston put forward a systematic method to evaluate the library signage system [27]. The calculation results will give the answer of how many signs are “enough” and “too many” for a library. Besides, the signage type, population and other criteria are presented together. Rodrigues et al. made a review about healthcare signage design and provided a set of

recommendations for the special users in healthcare [28]. Kinatader et al. focused on the tunnel evacuation and conducted a virtual reality tunnel to study the conflict information effect on tunnel evacuation [29]. Ronchi et al. used the Theory of Affordance to investigate the design of Variable Message Signs for road tunnel emergency evacuation [30].

C. CONTRIBUTIONS

Nowadays, most of the achievements are about the effect of evacuation signs and the design of intelligent evacuation signage system. For guidance system studies, dynamic route choosing plays a vital role and the effective route design research relies on the evacuation signage guidance effect studies.

As to the sign effect studies, there remain two main shortages.

1) The main methods to test sign detection are video analysis and after-drill questionnaires. However, it is hard to confirm whether the participants detect the signs indeed by videos. And the after-drill questionnaire is impressionable when they think back about the experiment details, possibly leading to wrong results. Although VR and MR are imported in the experiments, there is still a gap between the virtual environment and reality. What is more, MR equipment has not been fully developed. The sight is limited after wearing HoloLens (a typical MR device) and you will not know there is a sign at the wall bottom unless you turn your head direct to the sign. 2) It is normally assumed that all the pedestrians would follow the sign direction before. But sometimes not all the pedestrians detect the signs and even refuse to follow the signs after they see them. Fu et al. [12] and Xie et al. [16], [31] tend to consider the probability of detecting and following the signs by experiments. Even though, the surrounding people's influence on the detection and following probability has not been included and requires further study.

In this paper, a series of experiments are conducted to study the impact of surrounding population on the effect of emergency signs during building evacuation.

To solve the above problems, this paper imports eye tracking device to replace the traditional video analysis and after-drill questionnaires and then places disturbers to mislead the evacuee, studying the influence of the disturbers' number and types on detecting and following evacuation signs. The experiment results make the interaction between evacuation signs and evacuees clearer. It will improve the current simulation models and make the simulation results more realistic.

The rest of the paper is organized as follows. Section 2 describes the experiment details and the equipment involved. Section 3 displays the results of the experiments and summarize the rules. Section 4 made a model to study the influence of surrounding people on direction choosing and section 5 concludes the experiments findings and discusses the limitation.

2. METHOD AND EXPERIMENT

A. PARTICIPANTS

Totally 454 participants are involved in the experiments. All of them are the undergraduates aged from 19 to 22, which limits the experiment result scope. Only 36 of them are female. During the experiments, all the people involved wore the same uniform.

B. EXPERIMENT DESIGN

The experiments were carried out in a complicated building for student training in the university. The layout of the experiment environment is just shown in Fig. 1. All the participants are unfamiliar with the building. Before the drills, the participants were asked whether he/she had been there. If so, the result would be given up. All the information the evacuees (blue in Fig. 1) knew is that they are involved in an evacuation experiment and required to go out of the room and find an exit.

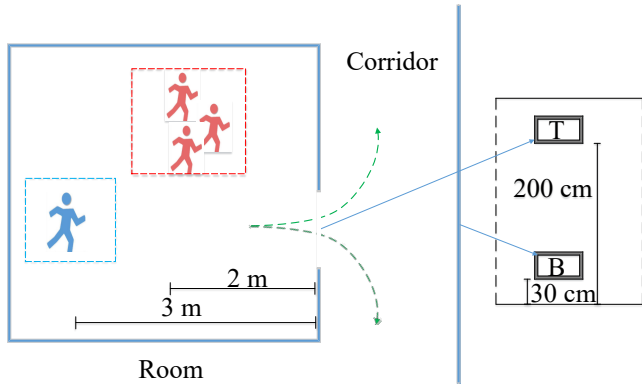


FIGURE 1. The description of experiment design. The blue person is the evacuee and the red people are disturbers/surrounding population (we set them to influence the choice of the evacuee). The disturbers' number could be 0, 1 and 3. In the experiments, blue person always stands in the blue blank and the red in the red zones. The sign has two position, T (on the top of the door inside) and B (at the bottom of the corridor wall against the door).

At the beginning of the experiment, the participant was guided into the room with an eye mask by an experimenter to avoid the routing memory. After that, the eye mask was replaced by the eye tracking glasses. The evacuee was back to the door all the time.

After wearing the eye tracking glasses shown in Fig. 2, the camera on the glasses records what the eyes see and the green spot on the screen represents the real-time gazing point. It is easy to get whether the participant detected the sign by analyzing the gazing point and gazing time. What is more, all the devices needed to wear are glasses and a recording phone, so the participants are able to move freely with the portable eye tracking glasses.

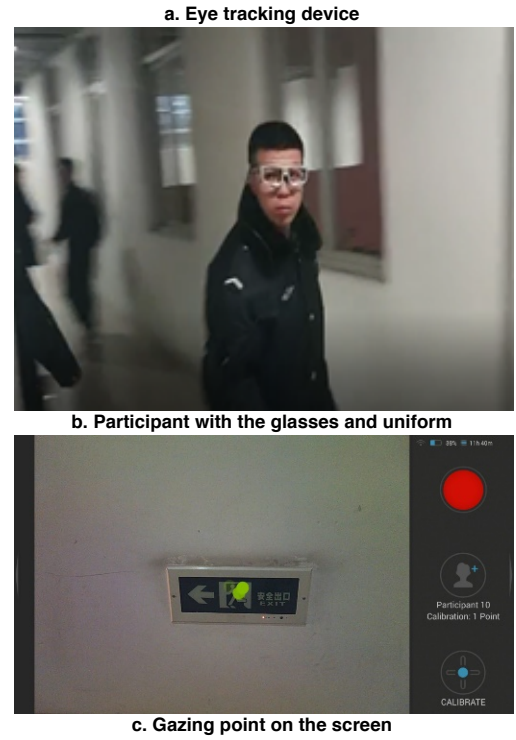


FIGURE 2. The eye tracking device

All the preparation has been finished. When the participant heard the alarm, he/she turned back and left the room. After the left or right direction in the corridor has been decided, the drill ends. It means that the participants needn't walk a long way in the corridor, so the uneven distance from the door to the bilateral staircases has no influence on the direction decision. In the experiments, the signs have two states (twinkling and not, twinkling means the sign is dark for 0.5s and bright for 0.5s, not twinkling means the sign is bright all the time), and two position (the bottom of the corridor against the door and the top of the inside door). The evacuation sign graphic is shown in Fig. 3. It directs right all the time. In addition, some other people are added in the room to disturb the evacuee's direction choice. In the experiments, the surrounding people's direction is always opposite to the sign, so the surrounding people are called disturbers here. The disturbers' number would be 0, 1 and 3 and they may be the acquaintances of the evacuee (they are classmates) or strangers. Just like Fig. 1 showing, the disturbers are in the front left of the evacuees, therefore we assume that participants perceive the positions of their surrounding neighbors at the beginning of the drill.



FIGURE 3. Evacuation sign

In the situations with disturbers, the surrounding people will leave the room earlier than the evacuee because they are nearer to the door. They will always choose left, opposite to the evacuation sign. Record the evacuee's direction decision under

the impact of the disturbers. The setting details are described in Table I. Particularly, every participant only took part in the experiment once.

TABLE I

Details of the experiments. In the 4th column “disturbers’ type”, A means acquaintance and S means stranger. In the 5th column “twinkle”, N means No and Y means Yes. In the 6th column “position”, B means corridor bottom and T means door top.)

order	participants number	disturbers' number	disturbers' type	twinkle	position	
1	33	0	-	N	B	
2	33			Y		
3	33			N	T	
4	33			Y		
5	32	1	S	N	B	
6	31		A			
7	28	3	S	Y		
8	23		A			
9	32	1	S	N	T	
10	30		A			
11	28	3	S	Y		
12	23		A			
13	32	1	S	N	B	
14	30		A			
15	28	3	S	Y		
16	23		A			
17	33	1	S	N	T	
18	30		A			
19	28	3	S	Y		
20	23		A			

3. RESULTS AND ANALYSIS

A. BASIC RESULTS

In the experiments, the most important results are whether the participant detects the evacuation sign and the final direction choice. With the help of eye tracking device, the staring time was collected. Only those staring longer than 0.1s are regarded as “surely detected the sign”. The detection results are much more accurate and easier to get than videos and questionnaires. In another series of experiments that we have conducted [32], 16 types of evacuation signs are involved to test the perceiving and detecting probability. The experiments are in the same room, so the results of the participants who didn’t detect the signs are collected as the results under no other people and no signs situation to compare. In the 159 trials, 85 evacuees chose right (the sign direction). As a result, a natural direction choosing probability is estimated as 53.5% for sign direction (right) and 46.5% for people direction (left).

B. THE INFLUENCE ON DETECTION

In this part, only the detection results are concentrated on. The sign detection frequency is an unbiased estimate, so the results are used to represent the probability of detection. All the detection probabilities in different situations are displayed in Fig. 4. The sign detection probability means the percentage of the participants whose eye sight fall in the signs for more than 0.1s.

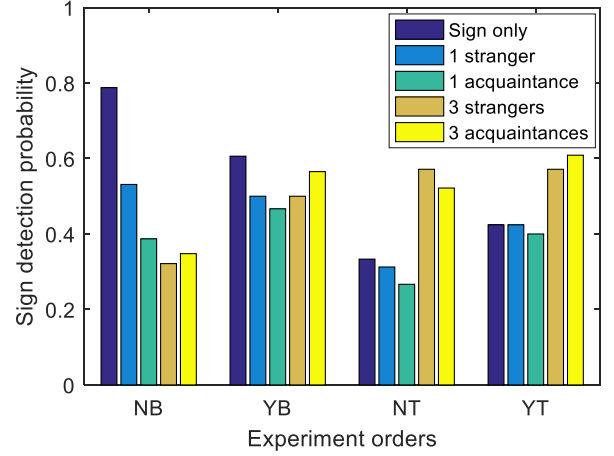


FIGURE 4. All the experiment detection probabilities. * In the X ticks, Y means twinkle, N means not twinkle, B means corridor bottom and T means door top.

1) IMPACT OF DISTURBERS’ NUMBER

Summarize the detection data and compare the sign detection probability, just like Fig. 5. To study the influence of the surrounding people’s number on sign detection, t-test is conducted between the situation with disturbers and that with no disturber. The p-values are shown in Table II.

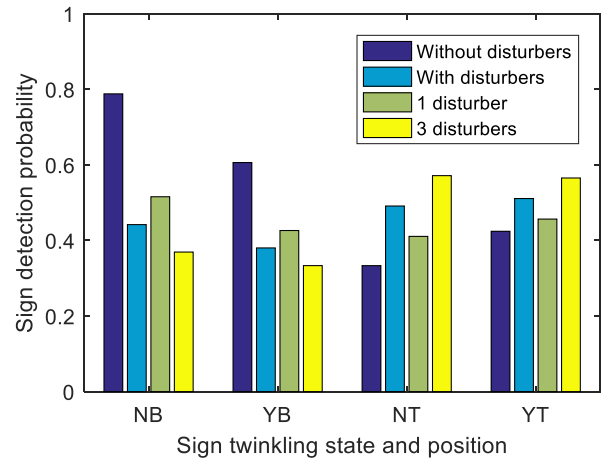


FIGURE 5. The sign detection probability with different disturbers’ number

TABLE II

The t-test p-value between the situation with disturbers and that without

sign	disturbers		
	with people	1 person	3 people
NB	3.3e-5	0.001	1.5e-5
YB	0.307	0.260	0.494
NT	0.443	0.674	0.052
YT	0.503	0.915	0.147

It is obvious that the detection probability increases with the disturber number for top signs, while it decreases for bottom signs according to Fig.5. For the corridor-bottom signs, the influence of disturbers’ number varies with the twinkling state. Under the significance level of 0.05, disturbers have a

considerable impact on the sign detection when it is not twinkling. The probability decreases from 79% to 52% and 37% with the disturber number increasing from 0 to 1 and 3 including acquaintances and strangers. The detection probability falls because the surrounding people cover the signages, named objective ignorance here. Nevertheless, for the door-top signs, the detection probability is not sensitive to the disturber's number changing from 0 according to the t-test results, but there is a noticeable rising tendency by 22% as the surrounding people increasing from 1 to 3. Especially, a chi-2 test has been conducted to compare the effect of 3 disturbers and 1 disturber. The results are shown in Table III. There is a strong significance to support that more people lead to less ignorance to the door-top sign. It is hard to be covered by surrounding evacuees but the detection probability is still low when no one is around. Interestingly, when someone delays the evacuees, the sign is more likely to be found according to the Chi-2 test result. It is due to the unfamiliar sign location. If the evacuee rushes out of the room, the sign is ignored easily. If they spend more time on leaving, the detection chance ascends, which is called subjective ignorance oppositely.

TABLE III

Chi-2 test result of the comparison between 3 disturbers and 1 for the door-top sign (including twinkling or not)

door-top sign	number of detecting the sign	number of not detecting the sign
1 disturber	44	81
3 disturbers	58	44
Chi-2 test	Chi-2 value 10.65, p-value 0.001	

2) IMPACT OF DISTURBERS' TYPE

In the experiments, different people types are involved in the drills. When the evacuees prepare to leave the door, the disturber could be an acquaintance (from the same class) or a stranger (from different departments or colleges). To study the different disturber type's impact, the experiment results are arranged and shown in Fig. 6 and Fig. 7.

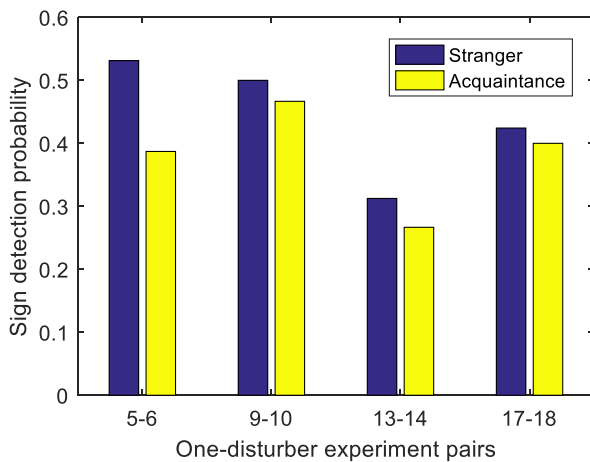


FIGURE 6. Probability comparison for 1 disturber

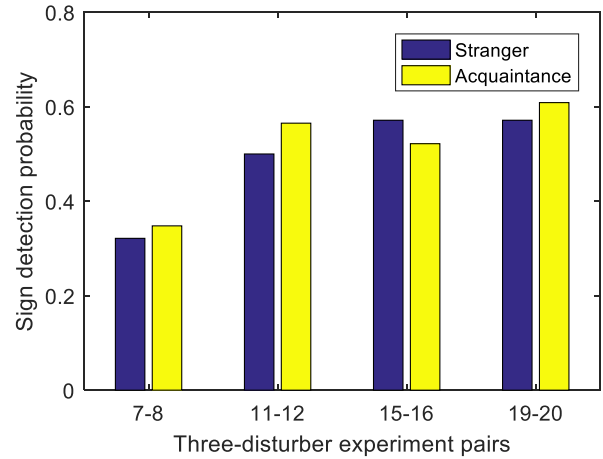


FIGURE 7. Probability comparison for 3 disturbers

The tendency is found that for 1-person experiment pairs, an acquaintance will lead to more ignorance to evacuation signs than a stranger, while for 3-people experiment pairs, 3 strangers tend to perform a higher ignorance probability. To further confirm the tendency, the Chi-2 test has been conducted like Table IV. Unfortunately, the test doesn't support the above opinion even at the significance level of 0.1. As a conclusion, disturbers' type (stranger or acquaintance) has little influence on the sign detection probability.

TABLE IV

Chi-2 test results between strangers and acquaintances

Experiment pairs	Chi-2 value	p-value
5-6	1.32	0.25
7-8	0.04	0.84
9-10	0.07	0.79
11-12	0.22	0.64
13-14	0.16	0.69
15-16	0.13	0.72
17-18	0.04	0.85
19-20	0.07	0.79

C. THE INFLUENCE ON DIRECTION

After the evacuees detected the evacuation signs, they would decide to follow the signs or not. This part concentrates on the impact factors of direction choosing. The direction choosing results are compared between the experiment groups detecting the signs and not detecting signs. In addition, the disturbers' type influence is also discussed here.

1) NOT DETECTING SIGNS

For the evacuees not detecting the sign, the situation is the same no matter whether there is a sign. Thus, collecting all the four types of signs as one situation "no sign". The correct direction (sign direction) choosing probabilities with different disturbers in the no-sign situations are shown in Table V and Fig. 8.

TABLE V

Direction distribution without signs. (In the number column, S means

Strangers, A means Acquaintances.)

Disturber	Total	Sign direction		People direction	
Number Type*	Number	Number	Percentage	Number	Percentage

0	159	85	53.5%	74	46.5%
1 S	72	18	25%	54	75%
1 A	75	14	18.7%	61	81.3%
3 S	57	26	45.6%	31	54.4%
3 A	45	17	37.8%	28	62.2%

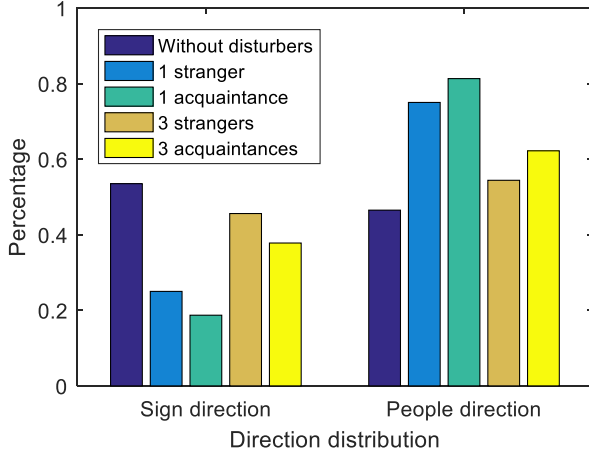


FIGURE 8. Direction distribution under no signs

To test the disturbers' number impact on the direction distribution, compare the situation with disturbers and that without disturbers. It is obvious that one person around has an important influence on the direction guidance with Chi-2 test p-value $6e-5$ for a stranger and $5e-7$ for an acquaintance. For one-person situations, sign direction probability decreases from 53.5% to 21.8%. However, three disturbers have less impact on the direction decision with Chi-2 test p-value 0.31 for 3 strangers, 0.06 for 3 acquaintances, and 0.18 for 3 disturbers totally, accepted the null hypotheses at the significance level of 0.05.

2) DETECTING SIGNS

Calculate the sign direction choosing probability of the evacuees who detected the signs and the comparison results are shown in Table VI and Fig. 9. Compared with no-sign situations, evacuation signs indeed increase the sign direction percentage distinctly, from 21.8% to 75.7% for one disturber and from 42.4% to 85.3% for three, showing the guiding effect of evacuation signages. Chi-2 test is conducted between the average sign direction probability with signs and with no signs. The p-values are all smaller than 0.001, strongly refusing the null hypotheses. The rise of sign direction choosing percentage represents the guidance effect of the evacuation signs.

TABLE VI

Sign direction choosing probability with different people around after signage detection

disturber	NB	YB	NT	YT	Mean	No Signs
1 S	52.9%	75.0%	100.0%	87.5%	73.9%	25.0%
1 A	68.8%	78.6%	92.9%	69.2%	77.2%	18.7%
3 S	80.0%	75.0%	93.8%	83.3%	84.8%	45.6%
3 A	85.7%	83.3%	81.3%	92.9%	85.7%	37.8%
0	73.1%	90.0%	100.0%	64.3%	80.3%	53.5%
1	60.6%	76.9%	95.7%	76.2%	75.7%	21.8%
3	83.3%	80.0%	87.5%	88.5%	85.3%	42.2%

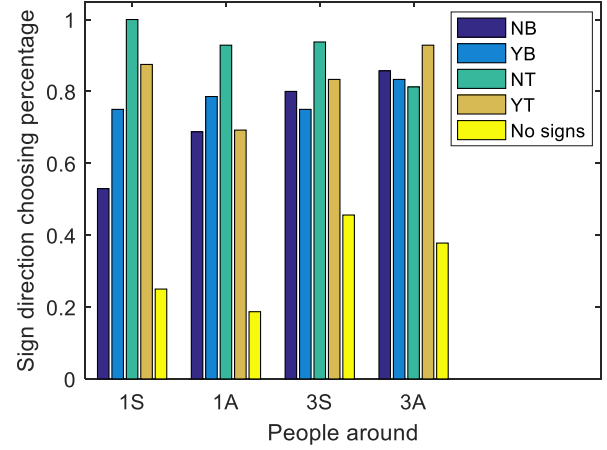


FIGURE 9. Sign direction choosing probability with different disturbers

For the door-top signs, the guidance effect is better than the corridor-bottom ones, no matter whether it is twinkling or not. Particularly, "NT" (not twinkle and locate on the top of door) has the best guidance effect among the four signages. For the corridor-bottom signs, "YB" (twinkle and locate at the corridor bottom) has a flat guidance effect around 80%. It is interesting to find that "NB" (not twinkle and locate at the wall bottom) has an increasing guidance effect with the around people changing from 1 stranger, 1 acquaintance, 3 strangers and 3 acquaintances.

3) IMPACT OF DISTURBERS' TYPE

Normally, people would like to follow someone familiar or some leader to escape rather than a stranger. Compare the data in Table VI and conduct fisher's exact test to study the effect of strangers and acquaintances. The results are displayed in Table VII.

TABLE VII

Fisher's exact test p-value between acquaintances and strangers

p-value	NB	YB	NT	YT
1 disturber	0.481	1.000	1.000	0.606
3 disturbers	1.000	1.000	0.600	0.580

The results are not consistent to our general knowledge that evacuees would like to follow their familiar person. The possible reasons are as follows: a) the drill duration was short so that the evacuees paid less attention to who the around people were; b) the drills were under safe conditions and the evacuees were not in panic; c) the repeated times are insufficient to express the difference. As a consequence, the probabilities under 1 disturber and 3 disturbers in Table VI can be regarded as the normal average following probability after detection.

4. SIMULATION

Wayfinding method is one of the most important part for evacuation simulation, in which evacuation signages play a vital role. In the past, most researchers simplified the interaction between pedestrians and signs. In current

simulation models, it is assumed that detecting the sign surely leads to the sign direction or else choose randomly, such as the “AI Route” [33] in *JuPedSim* (Jülich Pedestrian Simulation) [34]. Besides, the interaction between signs and evacuees is calculated individually. The influence of the group is excluded. Based on the experiment results, a new wayfinding logic is put forward especially for the people within rooms and the impact of surrounding people on the total direction choosing is involved in the new sign route model. To measure the influence on the direction choosing result distribution of the two logic, a simulation was conducted to compare the new method and the AI Route.

A. METHOD

Consider the simple room in Fig. 1, which was used to simulate the original direction choosing method and the new exacter way under the guidance of the emergency sign located at the corridor bottom. The process of choosing direction is divided into two steps, detecting signs and choosing direction. Simulate the occupants evacuating from the room and choose direction with the two methods. Assume only one person allowed through the door to make sure all the occupants make direction decision orderly.

The flow chart of the original method is shown in Fig. 10. The detection probability was set as 75% according to [32], and the random probability was set as 53.5% according to the experiment. If the pedestrian detected the sign, it would go right (sign direction), or it would choose a direction randomly. Obviously, the right percentage is like (1). In this paper, P_r represents the right choosing probability for certain person and $f(n)$ means the right choosing proportion under the crowd number n .

$$P_r = 0.75 \times 1 + 0.25 \times 0.535 = 0.884, \quad (1)$$

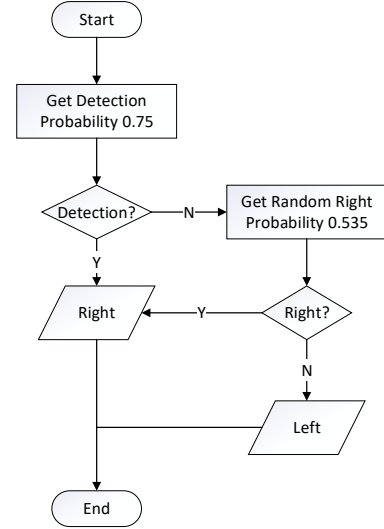


FIGURE 10. Flow chart of original method

In the new method, the impact of front people is considered. The new logic flow chart is shown in Fig. 11. The sign detection probability P_d relies on the number. Even if the sign was detected, the pedestrian may still choose left under the probability $(1-P_{c1})$. On the other hand, without the sign detection, the evacuee would decide to follow the front one person or not under the probability P_{c2} . The details of the probabilities are shown in Table VIII.

TABLE VIII

Simulation parameters			
N	P_d	P_{c1}	P_{c2}
0	0.788	0.731	0.535
1	0.460	0.621	0.782
>1	0.333	0.941	0.578

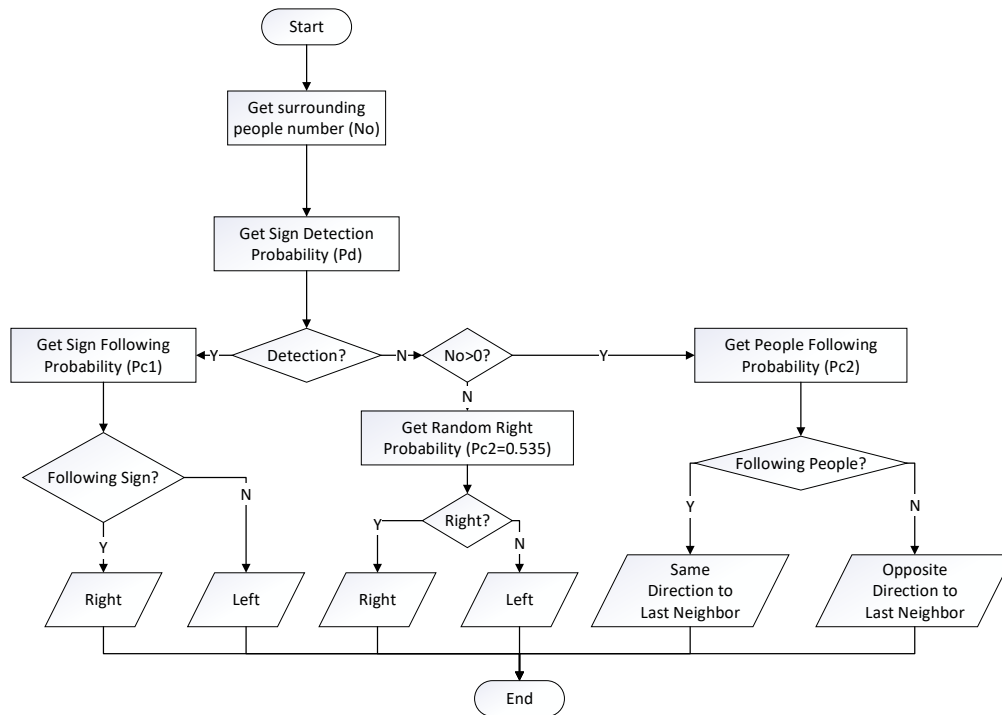


FIGURE 11. Flow chart of new method. In the core of the figure, No means the number of the surrounding people.

For the first pedestrian without any neighbor, the right probability is like (2), containing two situations, detecting and following the sign and ignoring the sign but choosing right randomly.

$$P_r(1) = P_{d-0}P_{c1-0} + (1 - P_{d-0})P_{c2-0} = 0.689, \quad (2)$$

For the second pedestrian, the right probability is like (3), including ignoring the sign but following the right front person or not following the left front person, besides detecting and following the sign.

$$P_r(2) = P_{d-1}P_{c1-1} + (1 - P_{d-1})[P_{c2-1}P_r(1) + (1 - P_{c2-1})(1 - P_r(1))] = 0.613, \quad (3)$$

For the next pedestrians, the calculation methods are the same because of the same parameter setting. The right situations are similar to the second pedestrian, just like (4). In another calculation way without the general formula (6), Equation (7) can be derived when the probability tends to be stable, which leads to the same result.

$$P_r(n) = P_{d-2}P_{c1-2} + (1 - P_{d-2})[P_{c2-2}P_r(n-1) + (1 - P_{c2-2})(1 - P_r(n-1))], \quad n \geq 3, \quad (4)$$

Getting (5) from (4), the general formula could be derived like (6). Naturally, the limitation under n going to infinity is $\beta/(1 - \alpha)$ which value is 0.664, due to α in the interval $(-1, 1)$.

$$P_r(n) = (1 - P_{d-2})(2P_{c2-2} - 1)P_r(n-1) + P_{d-2}P_{c1-2} + (1 - P_{d-2})(1 - P_{c2-2}) = \alpha P_r(n-1) + \beta, \quad n \geq 3, \quad (5)$$

$$P_r(n) = \alpha^{n-2}P_r(2) + \frac{\beta(1 - \alpha^{n-2})}{1 - \alpha}, \quad n \geq 3, \quad (6)$$

$$P_r(n) = \alpha P_r(n) + \beta, \quad n \geq 3, \quad (7)$$

It is still worth mentioning that the probability $P_r(n)$ is directly related to the third line parameters and the right probability of the second pedestrian, indirectly relying on other parameters in Table VIII.

B. RESULTS

The simulation was conducted under different total occupant number from 1 to 30. For example, at the situation of 15 occupants, the pedestrians would leave the room in order. The surrounding people number for everyone is 0, 1, 2, ..., 14. For each number, the simulation repeated 10,000 times and only the direction decisions were recorded. The simulation is a Monte Carlo verification of the calculation. The average right percentage $f(n)$ of each occupant number n is shown in Fig. 12. For calculation, $f(n)$ can be derived like (8). It is easy to find that the limitation of $f(n)$ equals to the limitation of P_r , with the value 0.578. Similarly, the right percentage of the original method equals to 0.884 constantly.

$$f(n) = \sum_{i=1}^n P_r(i), \quad (8)$$

Comparing the simulation results with the calculation results, the RMSE (Root Mean Square Error) is 0.001, proving the good fitting effect of the new logic.

Considering the calculation results, the right percentage difference is 19.5% and 27.1% for the first and second pedestrian respectively between original logic and the new one. With the involved number increasing continuously, the gap increases up to 22%. The huge and stable direction choosing distribution will lead to different evacuation route decisions and total evacuation time. To get better simulation results and safer building environment, the effect of surrounding people on evacuation signs must be considered in modeling and building design.

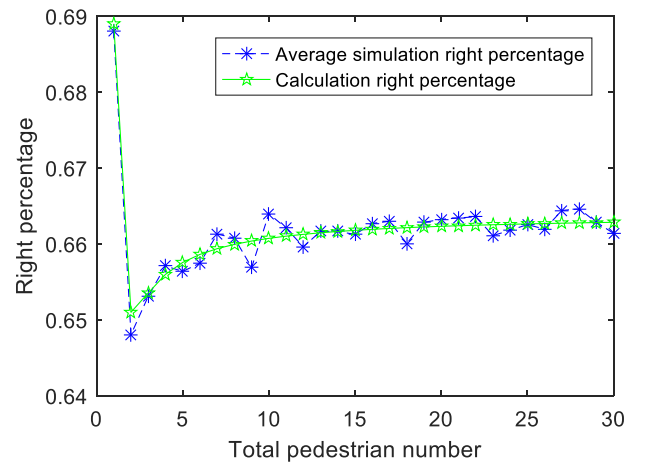


FIGURE 12. Results comparison between simulation and calculation for the new method

5. CONCLUSION

Emergency signage guidance is distinctly important in wayfinding during building evacuation, especially for crowd evacuation. This paper applied new experiment devices and concentrated on the impact of surrounding pedestrians on the evacuation sign guidance efficiency, which was not studied before. A series of experiments have been conducted and more than 500 students get involved to support the following conclusions:

- Eye tracking device is imported to test the evacuation sign detection and the influence of ignorance of signs is remarkable, which could be divided into two types, subjective ignorance and objective ignorance. For less surrounding people, subjective ignorance is more important while for more surrounding people, objective ignorance is more important.
- The normal signs detection probability (located at the bottom of corridor and bright all the time) is sensitive to the surrounding people, which decreases from 79% to 52% and 37% as the surrounding people number increases from 0 to 1 and 3.
- In the safe and quick evacuation experiment, strangers and acquaintances have similar effect on the sign detection probability and direction choosing probability.
- One disturber has an important influence on the sign guidance effect, especially on the following probability while three disturbers not. When signs are not detected, the sign direction (right) probability falls from 53.5% to 21.8% after

getting 1 disturber and the probability arises to 75.7% after detecting an evacuation sign.

e) a new sign interaction logic was put forward and the simulation results show that there is a remarkable influence (about 22% direction choosing difference) of others around on the effect of emergency signs.

Considering the sign guidance effect in evacuation models, the simulation results will be more valid, which is critical in evacuation simulation. During crowd evacuation, the disturbers' impact would occur everywhere and must be considered in both model simulation and evacuation plan design. As to the application perspective, some methods should be considered to avoid the objective ignorance and subjective ignorance and enhance the signs' guidance effect in public places. For example, add more signs in various position to prevent covered by crowds and some attractive factors should be designed to get more attention from pedestrians, such as flashing, bold fonts and so on.

Nevertheless, a quantitative function is expected to promote the existing evacuation models and the intelligent route designs in the future, especially for the complicated structure building evacuation simulation.

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