WAY-FINDING BEHAVIOUR AND GUIDANCE SYSTEMS

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Keywords: Evacuation, wayfinding, signs

Abstract
Human factors studies are reported with regard to evacuation behaviour. The studies were part of the BriteEuram project "MEPdesign". Almost 300 volunteers evacuated from an imitated ship's interior, their way-finding recorded through cameras. Two new systems for way-finding guidance were tested and compared with an IMO-compliant system. The proportion of way-finding errors was 24% for the existing IMO system, showing ample room for improvements. A new guidance system with directional information along the skirting board reduced the number of way-finding errors. This system is recommended because implementation is easy, and the information can be seen when smoke obscures the upper parts. Another new system, programmable in direction, was confusing. The recommendation is to base programmable systems on programmable arrows. "Fear of doors" was observed. Measures to alleviate these fears reduced the number of wayfinding errors with 2/3.

INTRODUCTION

The present paper is about wayfinding—the activity that occurs when you want to go to a particular destination. Wayfinding assumes that you have the goal to reach the destination established in your mind.

In emergencies, the passengers should find their assembly stations—relatively safe places from where they will be led to the lifeboats. The captain, or other responsible crew, will start the evacuation by alerting the passengers, and requesting them to go to the assembly stations. This interrupts their normal activities. Passengers will have the tendency to continue these normal activities, and will not be too eager to accept the situation. They may belittle the events of the disaster as "another exercise" (and, fortunately, exercises *are* more frequent than disasters). The first item of an evacuation is, therefore, convincing the public; for example, by a "this is your captain speaking" message on the public address system. When accepting the situation as serious, the passengers will prepare for evacuation. Private goals may be included: some may search first for their children, spouses, or other dear ones; others may return to their cabins in order to secure property (group and property binding, see May, 1999). When searching for the assembly stations, many passengers will imitate the behaviour of others (Pauls & Jones, 1980; which is in most cases a sensible thing to do) with the passengers in front leading the others.

The current studies investigated wayfinding as a function of layout and signs. Before describing the studies, I will briefly present a more complete list of factors influencing wayfinding behaviour:

- Layout of the environment
- Signs
- Knowledge or familiarity with the environment
- Emotional state.

Layout is an important factor. Wide open spaces and "promising" corridors are preferred over narrow, dark, or bad-looking spaces. Definitions of "promising" and "bad-looking" are subjective.

Signs are also important because they make the invisible visible. Passengers don't see the assembly station but see the sign "ASSEMBLY STATION →". Maps have a similar function; they show the destination as a bird's eye view and, if you know where you are, you know how to proceed.

Knowledge is a third factor. Sometimes, wayfinding is completely driven by the knowledge gained from experience, as when a passenger has used a particular route so many times that he doesn't notice the signs anymore. One of the problems of emergencies is the unfamiliarity of the evacuation route. The route may lead through areas that are, normally, forbidden to the public ("crew only"); the emergency exits may carry signs *alarm will sound* to prevent unauthorised access.

Emotional state, the last factor, is important in emergencies. Anxious passengers will mind the obvious only. They don't have the patience to study maps or to decipher complicated directions and instructions. They will rely on direct and obvious information such as what the immediate surroundings suggest (layout), on clear signs, on what they remember from previous experiences, or on what they see others do. A concrete example is panicked people who don't even consider the emergency exit and all rush towards the door where they entered (Edelman, Herz & Bickman, 1980). That is what also happened in the café in the Dutch city of Volendam on 1 January 2001 where approximately 100 people rushed to the one exit whereas the emergency exit remained unused. Considering the emotional state of the passengers, signs should be obvious and conspicuous. Signs placed in unfortunate positions will be ignored; and advertisements next to the signs will distract the passengers sufficiently long to cause them to miss the signs.

I did my first wayfinding study in 1993 (Boer *et al.*, 1993). I brought volunteers to their cabin, instructed them to find the assembly station, and recorded the time required. I found out that they wasted considerable time; that is, they lost the way. No observations were made *en route*. When I checked the route myself, I identified several problems. Some signs were placed out of sight; in a "nonvisual position" (see the report on the SCANDINAVIAN STAR fire, April 1990). Another problem was insufficient marking of the doors leading to the stairs. Another problem was that some volunteers were reluctant to cross *crew-only* territory.

The wayfinding studies presented here were done in the context of the BriteEuram project MEPdesign (Mustering and Evacuation of Passengers—Scientific Basis for Design)[1]. The procedure was the same as before: volunteers were escorted to their cabin, instructed to find the assembly station, and time was recorded. The main difference was that wayfinding behaviour was recorded with cameras; and that errors were recorded at every location. Moreover, design alternatives were tried out such as alternative wayfinding systems, one system programmable in direction (the "active system for the guidance of passengers" of the SOLAS maritime work programme, 1995). More details of the studies are presented in Boer (1998) and Boer and Vredeveldt (1999).

METHODS

Environment. Two mock-ups of a cabin area of a passenger ferry were built; one placed horizontally, the other tilted 15 degrees. Layout and dimensions of the mock-ups are presented in Figure 2. There were two assembly routes for each mock-up. The first led from the cabin to the point labelled "E" (the fire door at F door was open), through the door labelled "Y", (by then, the fire door was closed) to Point F, finally turning towards the assembly station at Point X. The alternative route led from the cabin to Point E, through Door X, to Point F, and finally towards the assembly station at Point Y. Both routes could be installed in either mock-up. The number of choice locations was 6 for each individual route.

Guidance. In addition to the regular assembly signs, the mock-ups had signs showing the way to the (imaginary) restaurant, the car decks, etc. Posters on the wall imitated advertisements. Figure 3 gives an impression of the interior. The assembly-route signs were made of whitish-yellow luminescent material printed on a green background, carrying the word "assembly station", the symbol for assembly, and an arrow. Note that the assembly signs were present throughout all test runs. The intensity of the assembly signs decreased log-log linearly. After 1 and 5 minutes in the dark, the afterglow was 0.270 cd/m^2 and 0.054 cd/m^2, respectively.

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[1] The European Commission, DG XII, covered 50% of the costs. Other partners in the project MEPdesign were: Quasar Consultants (Oslo), Royal Technical University (Stockholm), Danish Maritime Institute (Copenhagen), Det Norske Veritas (Oslo), shipowner Scandlines (Copenhagen), and Institut Français de Navigation (Paris).

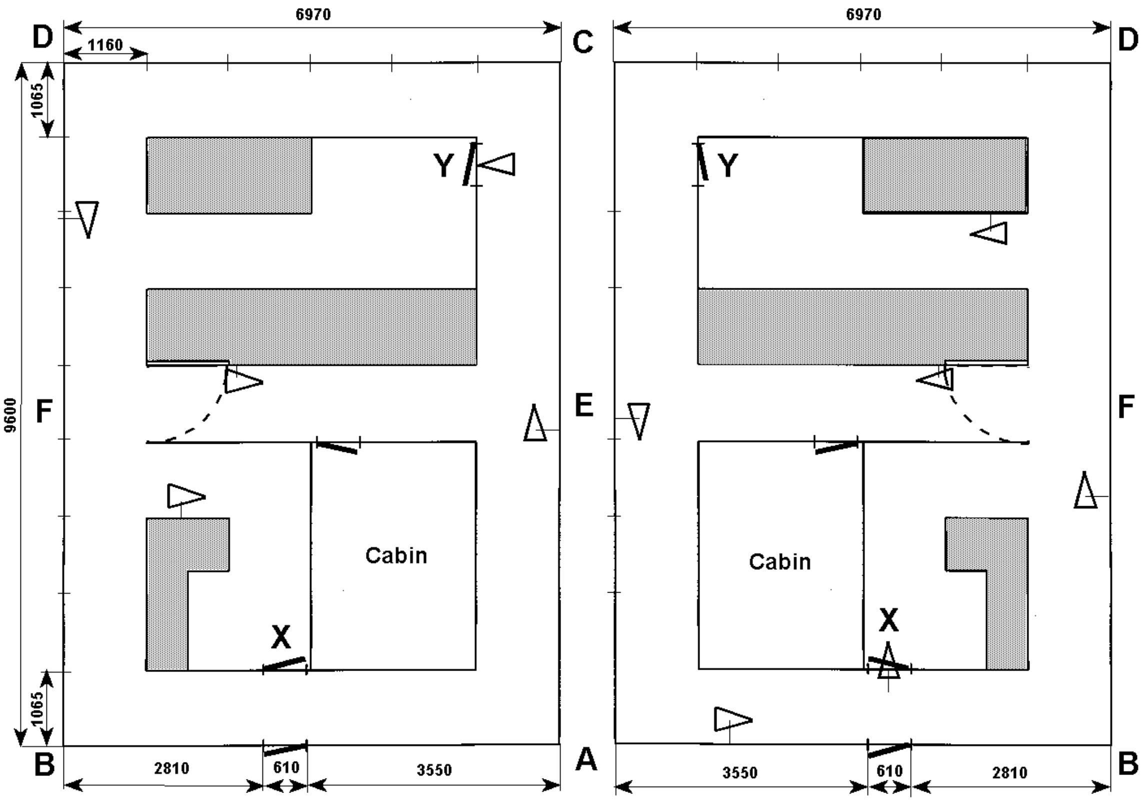

Figure 2. Layout of the mock-ups with the listed mock-up on the right, side CD 2.48 m higher than side AB. Corridor height was 2.18 m. Small triangles indicate the assembly signs.

In addition to the regular assembly signs, the mock-ups had signs showing the way to the (imaginary) restaurant, the car decks, or other cabins. Posters on the wall imitated advertisements. Figure 3 gives an impression of the interior. The assembly-route signs were made of luminescent material as whitish-yellow symbols printed on a green background, carrying the word “assembly station”, the symbol for assembly, and an arrow. Note that the assembly signs were present throughout all test runs. The intensity of the assembly signs decreased log-log linearly. After 1 and 5 minutes in the dark, the afterglow was 0.270 cd/m^2 and 0.054 cd/m^2, respectively.

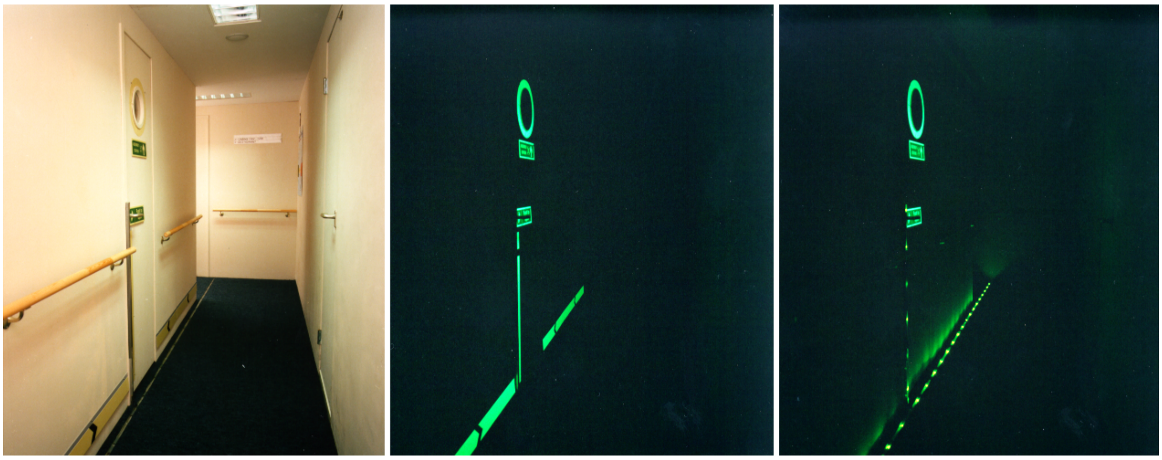

Figure 3. Interior of a mock-up in light and darkness (first two panels: luminescent skirting boards; right panel: LEDs. Note the experimental window in the door).

Three guidance systems were used, all based on low-location lighting.

1. An existing state-of-the-art IMO-compliant system consisting of "skirting-board" strips with photoluminescence. The strips, 80 mm wide, were the same colour as the assembly signs. They were attached 95-175 mm above the floor on one side of the corridor. Cabin doors interrupted them. The strips did not carry directional information except in corridor EF where they carried two arrowheads, 2 m apart.
2. System 2 was programmable based on light-emitting diodes or LEDs. The LEDs were mounted line-wise in the floor, 50 mm from the bulkhead with one LED every 0.2 m. Switching two adjacent LEDs in succession in one direction created apparent motion. With 8 switches made per second, the speed of the motion was 1.6 m/s.
3. A continuous line of arrows along the skirting board strips (similar to System 1, but direction indicated). Figure 3 shows the system.

Variables. The independent variables were

(a) participation as a group or an individual,
(b) guidance system,
(c) environment light or dark, and
(d) environment horizontal or listed.

The dependent variable was wayfinding errors, recorded for each choice location along the route. Interview response was a secondary variable. A random 50% of the participants were asked "how did you find your way" at the end of the last test run.

Procedure. 130 Participants performed groupwise (28 groups of 4 persons and 6 groups of 3 persons), 162 alone. Half an hour was reserved for a group; 15 minutes for an individual. At reception, participants received an instruction leaflet telling them that the ship could lean to one side; that they had to find their "assembly station" after a signal of the captain; that they were monitored with camera's; but that they should refrain from running and should take care. Groups were instructed to stay together.

Participants were escorted to their cabin with opaque goggles. This was a little unsettling, as they were dependent on the personal guidance of the test assistant. In the cabin, they took the blindfold off. The test assistant repeated the instructions, left them, and went over to the "assembly station". At the surveillance station, a second test assistant, the "captain", ordered the passengers to evacuate. The captain followed the progress on the monitor, and closed the fire door as soon as the passenger, or the last of the group, had left the cabin corridor. The captain aborted the test run after a way-finding error ("Please stop, you will be picked up"). The interview took place after the second test run.

RESULTS AND DISCUSSION

The results for the 4 independent variables are reviewed.

Groups and individuals. Groups did better than individuals: 9% of the test runs were aborted because of way-finding error as opposed to 32% aborted test runs for individuals. The explanation based on inspections by the surveyor was *error correction of groups*. Group members went one after the other, with the second member correcting the first member if he or she made a mistake. Corrections by the third or fourth group member were not observed.

A simple model that corresponds with these findings is "groups twice as intelligent as individuals" based on the consideration that a group will err only if both Members 1 *and* Member 2 make a mistake). The probability of an individual mistake was 32% in the study. The probability that Number 1 *and* Number 2 of a group make a mistake is simply 0.32 ^ 2 = 10% which approaches nicely the actual percentage observed (9.1%).

Guidance systems. Table 1 shows way-finding accuracy (proportion of test runs fully completed), including the effects of light and darkness for the different guidance systems.

Table 1. Behavioural success of 3 guidance systems: percentage runs completed in light and darkness (number of test runs in parentheses)

	Guidance system			
	Strips (reference)	**Strips improved**	**Program-able LEDs**	Average
Light	**74%** (n=23)	**72%** (n=18)	**66%** (n=36)	**70%** (n=77)
Dark	**76%** (n=21)	**94%** (n=18)	**76%** (n=37)	**80%** (n=76)
Average	**75%** (n=44)	**83%** (n=36)	**71%** (n=73)	**75%** (n=153)

The table suggested the following effects:

1. performance worst with the programmable system
2. performance best with arrows added to the strips (improved system)
3. irrespective of guidance system: performance better in the dark.

The interview data of Table 2 support these effects with significant results; that is, guidance systems and light-darkness had significant effects.

Table 2. Passenger opinion about the guidance systems: Percentage passengers mentioning a particular system as being helpful after the test runs (number of people questioned in parentheses)

	Guidance system			
	Strips (reference)	**Strips improved**	**Programmable LEDs**	Average
Light	**0%** (n=35)	**31%** (n=36)	0% (n=71)	**8%** (n=142)
Dark	**9%** (n=35)	**39%** (n=36)	**21**% (n=71)	**23%** (n=142)
Average	**4%** (n=70)	**35%** (n=72)	**11%** (n=142)	**15%** (n=284)

An important observation are the many way-finding errors with a state-of-the-art and IMO-compliant system--the *reference system* of Tables 1 and 2. Apparently, current regulations are insufficient. Further analysis is required. An example is the regulation that directional information along the skirting board is not required, except in dead-end corridors. The current study shows that directional information along the skirting board is very helpful; it reduced way-finding errors under fairly normal circumstances. Under worse circumstances, as when smoke obscures the upper portion of the interior, it may be the last chance for the passengers. Moreover, its implementation is easy. For these reasons, I would recommend adding directional information along the skirting board.

A disappointment was the failure of the programmable system. When perceived (*i.e.* in the dark), the LEDs embarrassed the people. At least, that is my interpretation. When I tried the LEDs out in a long empty corridor, the suggestion of direction was very clear. When I saw them again in the mock-ups, they were somewhat confusing because they followed corners and went up to a doorknob. Consider Figure 3 as an example. The LEDs nearby “walk” away from you to the door; the LEDs after the door walk towards you; whereas the LEDs walk upward on the doorpost. The result is confusion. Another reason of embarrassment is that you may perceive a line of walking LEDs as a moving area of darkness rather than as a moving area of light, a perception that is the same as when *solid objects* move in front of a continuous burning line of LEDs. Other people moving along the corridor would create the same perceptual pattern. The current studies thus suggest that programmable systems should *not* be based on apparent motion. Alternatives are arrows in fixed locations that can be programmed in direction.

Light or dark. An unexpected result was better wayfinding in the dark. I interpret this as due to a higher visual signal to visual noise ratio. The signals in this case are the assembly signs; the noise is all non-evacuation information like pointers to the restaurant and advertisements. In the light, the non-evacuation information is distracting and people can easily miss the signals. Again, this reveals inadequacy of current regulations. The regulation “signs should be free from obstacles” misses the point of information competition, and allows advertisements next to evacuation information, thus presenting obstacles in the psychological sense. Darkness changes the situation drastically. In the dark, the non-evacuation information disappears and only the light-emitting evacuation information remains visible. This made wayfinding easier.

Darkness cannot be recommended because it has negative effects also. In the dark, people will call, or yell, to one another in an attempt to unite. Other passengers will collide against one another. And darkness suggests lack of control, which increases feelings of panic among the passengers. Such negative effects should be avoided while retaining the advantage of darkness: the excellent signal-to-noise ratio. A possible solution is a special illumination that makes evacuation information very conspicuous, makes competing information difficult to see, and still illuminates the environment sufficiently for visual orientation. There are plans for further test and development of such a system.

Horizontal or listed. Another unexpected result was that wayfinding was unaffected by the ship leaning 15 degrees to one side. There were, however, effects on walking speed, but these effects were reported elsewhere (Bles, Groen & Boer, 2000; Bles, Nooy & Boer, 2001).

Bottlenecks. We now turn to the analysis of the different locations along the evacuation route. The number of way-finding errors was highest as doors (over 30%) and lowest at T-intersections (under 3%). Measures for improvement at passage doors were (a) larger distance between the door and the next corridor; (b) making the door conspicuous by adding a window or porthole (see Figure 3) and by marking the floor before the door. Measures at the cabin door were an assembly-route sign at the door’s inside.

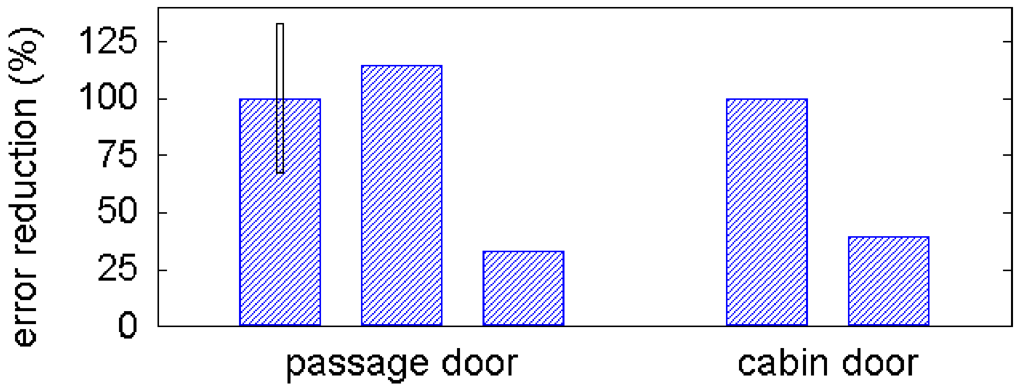

Figure 4. Reduction in way-finding errors relative to the “unimproved” situation (“100%”). The “stick” extending from the first bar shows the variation brought about by varying the distance between the door and next corridor. The next 2 bars show the failure and the success of two measures at the passage door. The last bar shows the success of an extra assembly-route sign at the inside of the cabin door.

The measures were subsequently tested, see Figure 4. The “stick” protruding from the first bar shows the effect of the distance between the passage door and the next corridor—

a highly significant effect. The next two bars show the effects of porthole and floor marking. One measure was ineffective; the other was highly effective; the number of passengers using the door increased very significantly. The last two bars show the effect of an assembly-route sign at the inside of the cabin door, another effective measure; the number of passengers immediately turning wrong after leaving the cabin decreased by 2/3.

I interpret the error at doors as a manifestation of psychological fear. The participants did not know what was behind the door. Doors can lead you into danger such as heavy machinery; doors can also lead you to confinement. The volunteers of the study were a little unsettled during the test runs, and may have perceived the door as threatening. If there is an open corridor close to the door, they prefer that corridor rather strongly[2].

DISCUSSION AND CONCLUSIONS

The studies show that human factors research can be applied with success to evacuation issues. The research suggests as an improvement that is easy to implement direction information along the skirting board. The research on a system with programmable direction based on apparent movement (in line with SOLAS research recommendations) led to a negative result. Rather, arrows with programmable direction should be used. The studies also show that current regulations are inadequate. For example, the regulations should address the negative effects of the distraction due to non-evacuation information.
In a "bottleneck approach", the studies revealed the locations that were most troublesome for the passengers. Solving the problems at the 2 most troublesome locations would already remove 90% of all way-finding errors! The bottleneck approach might be preferred over the guidance-system approach.

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[2] An interesting incident took place when I showed a colleague the mock-ups. He volunteered to do the same test run as the normal participants. I watched him on the TV cameras, saw him hesitating at the door, rejecting it, and preferring the corridor. When I told afterwards that many subjects also missed the door, he objected, saying he *had* used the door. I still don't believe him. Unfortunately, I had no video recordings made.

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Author biography

Louis C. Boer, PhD., studied human behaviour in emergencies for the last 10 years. He co-ordinated the BriteEuram project "Mustering and Evacuation of Passengers" 1997-2001. He advised on escapeway markings for train and road tunnels. In 2001, the Ministry of Interior Affairs asked him to study a national disaster—the new year's fire in Volendam. Boer appeared on national TV several times.