

Supporting Information

A survey based study concerning public comprehension of two component EXIT/NO-EXIT signage concepts

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Part A – The ISO and ANSI comprehension test methodologies

The increasing use of non-verbal presentation of information in buildings and other public places requires the development of methodologies for designing and evaluating new graphical symbols. In response to this requirement, the International Organization for Standardization (ISO) published the ISO 9186 series of standard under the general title *Graphical symbols – Test methods*. In particular, ISO 9186-1 (*Method for testing comprehensibility*) [1] specifies a method to test what proportion of people can comprehend the meaning of a graphical symbol correctly. The purpose of this method is to ensure that the proposed graphical symbols and the signs using them are readily understood by the intended users, often without the presence of supplementary text.

ISO 9186-1 is intended to be used by all the technical committees within ISO in developing specific graphical symbols for various industries. The method introduced by ISO 9186-1 is also recommended for use by other organisations concerned with the objectives of developing graphical symbols. The ANSI Z535 Committee of the American National Standards Institute, Inc. is responsible for developing standards for the design, application, and use of signs, colours, and symbols intended to identify and warn against specific hazards and for other accident prevention purposes. This committee adopted the same method as specified in ISO 9186-1 and published the equivalent ANSI Z535.3 standard, *Criteria for Safety Symbols* [2], albeit with a specific focus on the design and evaluation of safety symbols and safety signs.

ISO 9186-1 and ANSI Z535.3 outline the procedures for evaluating candidate symbols. These include the preparation of test materials, respondents, the test procedure, analysis of the results and more importantly, the acceptance criteria. The test materials can be either in printed form or presented on computer screens, which also includes internet presentation. For each one of candidate symbols, both standards require a minimum of 50 respondents in the test. This minimum size of subject population is selected to reach a balance between statistical reliability and ease of conducting the tests.

The main part of the method for evaluating symbols (and signs) is an open-ended comprehension test procedure. During the test, each symbol variant is shown to individual respondents along with the actual context or a description of background where the symbol would be placed. Then they are asked to provide a short definition of the meaning of the symbol through questions as follows.

What do you think this symbol means? [1]
Exactly what do you think this symbol means? [2]

In addition, they may be required to provide answers to what action they should take in response to the shown symbol. For safety symbols, they may also be required to predict the consequence if the instruction conveyed by a symbol is not followed [2].

The analysis of the results collected involves two steps. First, the collected definitions are categorised by independent judges (at least two) by comparing with the intended referent or message of the symbols as the correct answer for scoring. ISO 9186-1 recommends five standard categories (see Table A1). In particular, ISO 9186-1 states that although there are two ‘wrong’ categories, i.e. 2a and 2b, responses assigned to category 2b should be listed separately as they are particularly important if the symbol has relevance to safety situations. ANSI Z535.3 suggests a similar approach of categorisation using binary ratings. A correct answer would score 1 point and an incorrect answer would get 0 points. Incorrect answers would include wrong answers, no answer, or answers that are critical confusions, i.e. the opposite action is conveyed.

Table A1: Categorisation of responses in ISO 9186-1 [1].

Category	Meaning
1	Correct
2a	Wrong
2b	Wrong and the response given is the opposite of the intended meaning
3	The response given is “Don’t know”
4	No response is given

The final step of the analysis is to compare the scores, i.e. the percentage of correct and incorrect answers in each category, with the recommended criteria for acceptance. The criteria for acceptance may vary with the importance of the message conveyed by the symbols or the level of severity of the hazard. For symbols of general purpose, ISO 9186-1 suggests 66% for a standard symbol without supplementary text to be accepted. Since ANSI Z535.3 deals with safety symbols, much higher criteria are recommended: a minimum of 85% correct responses and a maximum of 5% critical confusions.

If several symbols conveying the same message meet the criteria for acceptance, ANSI Z535.3 suggests a few general considerations for selecting the symbol to use, such as selecting the symbol that requires the least amount of context, the symbol that is least abstract and the symbol that has a higher level of discrimination, recall and legibility etc. A symbol that fails to meet these criteria could be either rejected, modified or retested. In some cases, a failed symbol may still be used along with supplementary messaging or be supplemented by specialised training for the intended user population.

Part B – The survey method employed in the study

The survey consisted of two parts, four questions relating to personal demographics and ten questions relating to signage interpretation.

The four personal demographics questions concerned participants’ age, gender, country/region of residence and more importantly, whether their profession or work is related to fire safety. This was to identify participants who worked in the fire engineering or safety so that their replies could be assessed separately in case of professional bias.

The second part of the survey included three sections. The first section is a comprehension test as in [1] and [2], in which the participants were shown each of the signage options along with the context through the recorded video footage, and then they were asked to explain in their own words what they thought the sign indicated. The specific question was:

What do you think the signage above the door indicates?

The replies were assessed independently by two judges to determine whether the participants had correctly interpreted the meaning of the signs. The judges could interpret the replies in several ways as follows.

- The participant clearly understood the meaning and intent of the signs, and a correct action is conveyed.
- The participant apparently understood the signs; but they were somewhat uncertain or confused. This is indicated either by the participant stating that they were confused or by the judges deciding that their statement indicated that they were somewhat uncertain with the actual meaning.
- The participant clearly misunderstood the meaning and intent of the signs. Of the incorrect interpretations, those which elicit the opposite action would be categorised as critical confusion.
- The participant's replies were sarcastic or flippant and so were excluded.

Any differences in opinion between the two judges were discussed and resolved so that both judges finally agreed on the assessment of each reply. This section of the survey was intended to measure how intuitive the proposed signage options were to the members of the public with or without fire safety background.

In the second section, the participants were given the correct interpretation for each of the signage options, and they were asked to indicate their level of agreement with the interpretation using a five-point Likert Scale (i.e. strongly disagree, disagree, neither disagree or agree, agree and strongly agree). The correct interpretation for state 1 i.e. the EXIT condition, for both activation option 1 (static) and 2 (flashing), was:

The signage shown below clearly suggests to me that the emergency EXIT route is available for use.

The correct interpretation for state 2 i.e. the NO-EXIT condition, for both activation option, 1 (static) and 2 (flashing) was:

The signage shown below clearly suggests to me that the emergency EXIT route is no longer available for use.

This section was intended to measure the level of agreement that the public had with the intended interpretation of the signs.

In the third and final section, the participants were shown the two signage configurations with the same meaning side by side for the two EXIT activation options and two NO-EXIT activation options respectively. The participants were then asked to select which of the two configurations most clearly indicated the stated intention of the sign. The precise question for the two EXIT activation options, 1 (static) and 2 (flashing), was:

Of the two signage options shown below, which do you think most clearly suggests to you that the emergency EXIT route is available?

The precise question for the two NO-EXIT activation options, 1 (static) and 2 (flashing) was:

Of the two signage options shown below, which do you think most clearly suggests to you that the emergency EXIT route is no longer available?

This section was intended to examine participants' preference between two signage options (i.e. the static lit sign and the flashing sign) that convey the same message.

Part C - Analysis of the potential gender and profession difference in signage interpretation

The numbers of correct and incorrect replies for the interpretation of each signage option based on gender are presented in Table C1. The percentage of correct/incorrect interpretation varies between different configurations; however, there is no statistically significant difference between males and females in their comprehension of each configuration at a significant level of 0.05. The Fisher's exact test p-value is 0.75 for activation option 1, state 1 (AO1S1), and the chi-square test results for activation option 1, state 2 (AO1S2), activation option 2, state 1 (AO2S1) and activation option 2, state 2 (AO2S2) are $\chi^2(1, N = 422) = 0.77, p = 0.38 > 0.05, \chi^2(1, N = 419) = 0.002, p = 0.96 > 0.05$ and $\chi^2(1, N=420) = 0.05, p = 0.82 > 0.05$ respectively.

Table C1. Replies to signage interpretation question divided by gender†.

Category	AO1S1		AO1S2		AO2S1		AO2S2	
Male/Correct	248	98.0%	203	79.9%	188	74.3%	190	75.4%
Male/Incorrect	5	2.0%	51	20.1%	65	25.7%	62	24.6%
Female/Correct	164	97.6%	140	83.3%	123	74.1%	125	74.4%
Female/Incorrect	4	2.4%	28	16.7%	43	25.9%	43	25.6%

† Two persons who prefer not to state their gender and a few flippant replies are excluded.

The numbers of correct and incorrect replies for the interpretation of each signage configuration based on profession are presented in Table C2. Similarly, there is no statistically significant difference between fire and non-fire professionals in their comprehension of each signage configuration at a significant level of 0.05. The Fisher's exact test p-value for AO1S1 is 0.52, the chi-square test results are $\chi^2(1, N = 424) = 1.78, p = 0.18 > 0.05, \chi^2(1, N = 421) = 0.90, p = 0.34 > 0.05$ and $\chi^2(1, N = 422) = 1.67, p = 0.20 > 0.05$ for AO1S2, AO2S1 and AO2S2 respectively.

Table C2. Replies to signage interpretation question divided by profession†.

Category	AO1S1		AO1S2		AO2S1		AO2S2	
Fire/Correct	191	98.5%	164	84.1%	140	72.2%	151	77.8%
Fire/Incorrect	3	1.5%	31	15.9%	54	27.8%	43	22.2%
Non-fire/Correct	223	97.4%	181	79.0%	173	76.2%	165	72.4%
Non-fire/Incorrect	6	2.6%	48	21.0%	54	23.8%	63	27.6%

† A few flippant replies are excluded.

Part D - Examples of correct and incorrect interpretation

D1.Examples of correct interpretation of AO1S1

'Go out of this door in an emergency.' (a non-fire professional)

'That you should use the door as an escape route in an emergency.' (a non-fire professional)

'The green light indicates this is a fire EXIT.' (a fire professional)

'This is an EXIT door for emergencies and I will be safe if I go through this door.' (a fire professional)

D2.Examples of incorrect interpretation of AO1S1

'Fire EXIT to the right.' (a non-fire professional)

'A person running. But where? You do not run down stairs for safety reasons. The elderly do not run down stairs.' (a non-fire professional)

'The sign shows that EXIT is located at the right side.' (a fire professional)

'the emergency EXIT is in the right side (go right during emergency).' (a fire professional)

D3.Examples of incorrect interpretation of AO1S2

'As we have two indicating different things, I am unsure.' (a non-fire professional)
'It is rather confusing to see a fire EXIT sign next to the no EXIT sign.' (a non-fire professional)
'Very confusing. Was an EXIT earlier but is not available now?' (a fire professional)
'Very confusing but the EXIT sign is not lit so it most likely means there is a fire EXIT route but not through this door. Not clear at all.' (a fire professional)

D4.Examples of incorrect interpretation of AO1S2 with critical confusion

'Fire EXIT only, NO-EXIT at other times.' (a non-fire professional)
'Only EXIT through this door during an emergency. No "normal" EXIT through this door.' (a non-fire professional)
'Fire EXIT only. No EXIT for normal daily use.' (a fire professional)
'Fire escape route is through the door which is not normally used for traffic.' (a fire professional)

D5.Examples of incorrect interpretation of AO2S1

'I am confused as to what the blinking means (and annoyed by it)... perhaps the EXIT is not going to be usable for much longer? or it's indicating this is the EXIT we should use Right Now, but the confusion makes me hesitate, not good in emergencies.' (a non-fire professional)
'The light bulb is not working.' (a non-fire professional)
'escape route; this type of flashing would make me question if anything is wrong with the electronics.' (a fire professional)
'Confusion as to why it is flashing, is it safe or not?' (a fire professional)

D6.Examples of incorrect interpretation of AO2S2

'faulty sign.' (a non-fire professional)
'signs not adequately installed, meaningless.' (a non-fire professional)
'That it is an EXIT door however the light is broken as it is flashing.' (a fire professional)
'Not Sure. Probably broken.' (a fire professional)

D7.Examples of incorrect interpretation of AO2S2 with critical confusion

'That it is normally not an exit but is an emergency exit.' (a non-fire professional)
'This door is for exits in emergency only.' (a non-fire professional)
'confusing, but i'd think that the door is not a general EXIT, but still a fire EXIT.' (a fire professional)
'Fire escape route is through the door.' (a fire professional)

D8.Concerns about the contradictory and confusing nature of having both EXIT and NO-EXIT signs visible from members of the fire professional community

'A contradiction of use. In a fire the fire EXIT sign should illuminate causing confusion and possible loss of life.'
'That no one is carrying out fire safety inspections as these signs clearly contradict each other.'
'Signs with conflicting messages, could cause confusion. Might mean this door is for emergency escape only, do not use as a normal EXIT door?'

Part E - Statistical tests and results

The exact McNemar's test with the Bonferroni correction (i.e. $\alpha = 0.05/6 \approx 0.0083$) showed that there was a statistically highly significant difference in the proportion of correct interpretation between

AO1S1 and each of the three other configurations (AO1S2, AO2S1 and AO2S2), $P < 0.000001$ (see Table E1-E3).

Table E1. Crosstab table for comparing AO1S1 and AO1S2.

		AO1S2, deactivated EXIT, static NO-EXIT		Total
		Correct	Incorrect	
AO1S1 Static EXIT, deactivated NO-EXIT	Correct	338	76	414
	Incorrect	6	3	9
Total		344	79	423

Table E2. Crosstab table for comparing AO1S1 and AO2S1.

		AO2S1, flashing EXIT, deactivated NO-EXIT		Total
		Correct	Incorrect	
AO1S1 static EXIT, deactivated NO-EXIT	Correct	309	103	412
	Incorrect	4	5	9
Total		313	108	421

Table E3. Crosstab table for comparing AO1S1 and AO2S2.

		AO2S2, deactivated EXIT, flashing NO-EXIT		Total
		Correct	Incorrect	
AO1S1 static EXIT, deactivated NO-EXIT	Correct	310	102	412
	Incorrect	5	4	9
Total		315	106	421

The exact McNemar's test with the Bonferroni correction (i.e. $\alpha = 0.05/6 \approx 0.0083$) showed that there was no statistically significant difference in the proportion of correct interpretation between AO1S2 and AO2S1 ($P=0.021 > 0.0083$), AO1S2 and AO2S2 ($P=0.015 > 0.0083$), AO2S1 and AO2S2 ($P=0.92 > 0.0083$) (see Table E4-E6).

Table E4. Crosstab table for comparing AO1S2 and AO2S1.

		AO2S1, flashing EXIT, deactivated NO-EXIT		Total
		Correct	Incorrect	
AO1S2 deactivated EXIT, static NO-EXIT	Correct	254	88	342
	Incorrect	59	20	79
Total		313	108	421

Table E5. Crosstab table for comparing AO1S2 and AO2S2.

		AO2S2, deactivated EXIT, flashing NO-EXIT		Total
		Correct	Incorrect	
AO1S2 deactivated EXIT, static NO-EXIT	Correct	272	71	343
	Incorrect	44	35	79
Total		316	106	422

Table E6. Crosstab table for comparing AO2S1 and AO2S2.





		AO2S2, deactivated EXIT, flashing NO-EXIT		Total
		Correct	Incorrect	
AO2S1 flashing EXIT, deactivated NO-EXIT	Correct	262	49	311
	Incorrect	51	57	108
Total		313	106	419

Part F - Statistical tests and results

In a previous study undertaken by the authors, an international survey was undertaken to identify which of four novel dynamic emergency sign concepts was the most intuitive [3] and hence could be correctly understood by the most people without prior training or instruction. The proposed four signage designs were intended to negate the original exit signage information, essentially indicating that a normally available exit route was no longer considered viable and so should not be used (see Table F1). In order to assess the level of understanding of the proposed negated signage concepts amongst the general population, a total of 613 people across the world were surveyed. Participants' interpretation of the negated signs, their level of agreement with the specified meaning and their preference among the four designs for the intended use were analysed and presented in [3]. The survey methodology used to assess the interpretation and preference of the participants is similar to that described in the main paper (as described in Part B). The results concerning the correct interpretation of each of the four signage concepts (as presented in [3]) are summarised in Table F1.

Here we revisit the analysis, extending it to include an assessment of the rate of critical confusion for each of the signage concepts using the ISO and ANSI comprehension test methodologies (as described in Part A). The intended meaning of the original base sign (without activating the modified features) is that an acceptable emergency exit route is to the left, in the direction of the arrow. When activated, the modified signs are intended to convey the message that that the normally available exit route to the left, is no longer considered viable and so should not be used. Therefore, a critical confusion is defined as any interpretation that suggests that the participant still believes that the route to the left is currently viable and/or that they would proceed to the left as suggested by the original base sign. On reassessing the incorrect replies the critical confusions were identified and reported in Table F1. As seen in Table F1, the S3 design (with a large red cross through the entire sign) not only achieved the best correct interpretation rate (as reported in [3]) but also the lowest critical confusion rate and is the only design satisfying the ANSI criteria for acceptance.

Table F1. Percentage of correct interpretation and critical confusion of four negated signage designs.

Negated signs	Total*	Correct interpretation rate	Critical confusion rate
S1 	587	84.2% (494)	2.9% (17)
S2 	579	57.9% (335)	13.0% (75)
S3 	581	92.3% (536)	0.5% (3)
S4 	553	75.8% (419)	5.1% (28)

* Of the 613 participants, those who did not answer or failed to provide a legible answer were excluded.

References

- [1] ISO 9186-1:2014, Graphical symbols - Test methods - Part 1: Method for testing comprehensibility
- [2] ANSI Z535.3-2011, American National Standard for Criteria for Safety Symbols, American National Standards Institute, Inc.
- [3] Galea, E. R., Xie, H., Deere, S., Cooney, D., and Filippidis, L., 2017, An international survey and full-scale evacuation trial demonstrating the effectiveness of the active dynamic signage system concept. *Fire Materials*, Vol 41, 5, pp 493-513