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Dissuasive exit signage for building fire evacuation

Joakim Olander [a], Enrico Ronchi [b, *], Ruggiero Lovreglio [c], Daniel Nilsson [b]

[a] Holmes Fire, New Zealand
[b] Department of Fire Safety Engineering, Lund University, Sweden
[c] Department of Civil and Environmental Engineering, Technical University of Bari, Italy

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ABSTRACT

This work presents the result of a questionnaire study which investigates the design of dissuasive emergency signage, i.e. signage conveying a message of not utilizing a specific exit door. The work analyses and tests a set of key features of dissuasive emergency signage using the Theory of Affordances. The variables having the largest impact on observer preference, interpretation and noticeability of the signage have been identified. Results show that features which clearly negate the exit-message of the original positive exit signage are most effective, for instance a red X-marking placed across the entirety of the exit signage conveys a clear dissuasive message. Other features of note are red flashing lights and alternation of colour. The sense of urgency conveyed by the sign is largely affected by sensory inputs such as red flashing lights or other features which cause the signs to break the tendencies of normalcy.

1. Introduction

The use of exit signage is an important component in people way-finding in case of evacuation. In this context, evacuees can have a tendency to move towards familiar routes (Sime, 1985). This is associated with a possible sub-optimal use of emergency exits, i.e. people tend to go towards the entrance of the building rather than using emergency exits (Nilsson, 2009). However, evacuation experiments in buildings have yielded results which show that emergency signage can influence the behaviour of people during an evacuation and that this depends on how visible the signs are. Experimental work (Xie, 2011) showed that only 38% of people actually detect conventional static emergency signage (e.g. based on ISO standards (International Standards Organization, 2011)), even if they are provided with unobstructed vision to signage directly in front of them. The importance of emergency signage is associated with the compliance of people with it (Duarte et al., 2014; Vilar et al., 2014; Wogalter et al., 1993, 1989). Signage has also been investigated in Virtual Reality in relationship with environmental features (Vilar et al., 2013).

A possible way to improve people awareness of the existence of emergency signage is the use of flashing lights in the immediate proximity of the emergency sign (Nilsson, 2009). This will alert occupants of the specific emergency sign and in most cases influence the occupants to use that particular path for egress making it possible to alter behaviours such as heading back down the known path.

The use of for example flashing lights, or other dynamic features incorporated into emergency signage is generally called dynamic signage system. Experimental studies show that an increase from 38% to 77% in the visibility of the signage could be observed when comparing dynamic signage systems to the more conventional static emergency signage systems (Galea et al., 2014). This conclusion was obtained by replicating an experiment performed with static signs using a dynamic exit sign. The dynamic nature of the sign was obtained using a set of LED lights which activated and pointed towards the exit. In other words, a larger portion of the egressing occupants is able to detect the sign and subsequently follows the instructions provided by it. Processes that subsequently impact observers' choice to follow signage are discussed frequently within relevant literature. A common classification includes a four step assessment based on the answer to these questions: Is the sign

* Corresponding author.
E-mail address: enricoronchi84@gmail.com (E. Ronchi).

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visible to the observer? Is the sign noticed by the observer? Is the sign correctly interpreted by the observer? Does action occur due to the signage impacting the observer? (Ronchi et al., 2012; Xie, 2011).

The act of incorporating dynamic features into emergency signage has been researched in different research projects. Experimental studies investigated how egress route can be indicated through the use of evacuation signage provided with lit green arrows or red crosses (Bryant and Giachritsis, 2014). Another experiment found that an egress route equipped with green flashing lights was used more frequently than one without (Fridolf et al., 2013). A virtual reality study showed that the design of flashing lights impact the capability of exit signs to help people identifying the existence of an egress route as well as route choice (Ronchi and Nilsson, 2015). In addition, active dynamic emergency signage can be used to both alert occupants of existing signage and also affect their choice of egress path. These are systems capable of altering which path is shown as the preferred egress route by altering the meanings of the emergency signage (Galea et al., 2014). This can be done by altering some characteristics of the sign to display a negative or dissuasive message, with the goal of dissuading the use of a particular path, and hence leading occupants down the egress routes which are not marked as negative or dissuasive.

This paper aims to research and establish which type of emergency signage is best suited to convey a negative or dissuasive message to egressing occupants informing them that a certain egress route should not be used. This is done by performing a questionnaire study in which a set of features of selected dissuasive signs have been evaluated. The questionnaire design has been based on the Theory of Affordances (Gibson, 1977; Hartson, 2003). The analysis of results has been done using both statistical tests and a mixed ordered logit approach (Greene, 2010).

2. Methods

A study was carried out at Lund University (Olander, 2015) to study the characteristics of dissuasive exit signage in which participants had to evaluate dissuasive exit signage using a questionnaire. The questionnaire was designed using the Theory of Affordances (Gibson, 1977; Hartson, 2003), specifically investigating the affordances associated with different types of dissuasive exit signage. Paired comparisons were used in the questionnaire to assess the best layout for a dissuasive exit signage. This technique allows having quantitatively comparison of different layouts against each other and it provides the advantages of getting statistically robust results (Brown and Peterson, 2009; Noor, 2013). Moreover, the questionnaire included a further task, in which participants need to assess the functional affordance of several dissuasive exit signage layouts using a 5-point Likert scale.

The evaluation of the impact of different features of the installations on the perceived affordance has been made using three different methods, namely 1) binomial testing of the paired comparisons, 2) analysis of the Likert scale responses and 3) a mixed ordered logit modelling approach.

2.1. The Theory of Affordances

The questionnaire that was used in this study is based on the Theory of Affordances (Gibson, 1977). This theory assumes that an object is perceived in relation to what it offers or affords an individual. An affordance is, hence, what the object offers the individual in relation to his or her goal. In other words, an affordance can be used to explain how people perceive things that they sense. For example, people would not only see an emergency exit as a door with a sign on it, but that door is interpreted as a mean of reaching a safe place. A modified version of this theory has been provided by Hartson (Hartson, 2003). This later version assumes that the assessment of what an object offers people can be made in relation to different affordances, namely how an object can be (1) sensed (i.e. Sensory Affordance), (2) understood (i.e. Cognitive Affordance), (3) physically used (i.e. Physical Affordance), or (4) if it fulfil its intended goal (i.e. Functional Affordance). Therefore, this extended version of the theory allows researchers investigating the effectiveness of different evacuation systems depending on the assistance they offer to see, understand, use and fulfil the goal of the systems.

By systematically exploring the sensory, cognitive, physical and functional affordances provided by an evacuation system, it should be possible to identify the advantages and disadvantages of an evacuation system. Since the system under consideration is a visual system (signage), physical affordance is not taken into consideration in this instance.

The theory can be used to qualitatively analyse an array of possible system designs to rule out the most appropriate system in relation to a design goal. In addition, the theory has been used to design an affordance-based questionnaire, which explores different types of affordances in relation to the examined system.

2.2. Mixed ordered logit modelling

This work adopts a mixed ordered logit approach to investigate the impact of different features of dissuasive exit signage on the perceived functional affordances of this signage. Mixed ordered logit models are a useful tool to achieve this goal since they provide a quantitative statistical method to perform behavioural studies aimed at obtaining a better understanding of the factors affecting human behaviour and predicting behavioural responses (Lovreglio et al., 2015). In particular, this modelling approach provides a relevant methodology for capturing the sources of influence (independent variables) that explain the ordinal variable (dependent variable) (Greene, 2010).

Let y_i be an ordinal variable which can vary between 0 and m ($m \in \mathrm{N}^+$) for the i individual ($i = 1, \ldots, k$). It is possible to define an unobserved (or latent) continuous variable (y_i^*) defined in an utility space characterized by threshold utility points ($\mu_0, \ldots, \mu_{m-1}$) which is related to y_i ordinal variable according to Equation (1). This latent utility has an error component (ε) which is distributed as a logistic random distribution with expected value (μ) equal to zero and variance (σ^2) equal to $\pi^2/3$ (Greene, 2010).

$$\begin{aligned} & y_i^* = \boldsymbol{\beta}\cdot\boldsymbol{x_i} + \varepsilon, \quad \varepsilon \sim L(\mu|\sigma), \mu = 0, \sigma = \pi\Big/\sqrt{3} \\ & y_i = 0 \quad if - \infty < y_i^* \le \mu_0 \\ & y_i = 1 \quad if\, \mu_0 < y_i^* \le \mu_1 \\ & \ldots \\ & y_i = m \quad if\, \mu_{m-1} < y_i^* \le +\infty \end{aligned} \tag{1}$$

where $\boldsymbol{x_i} = \{x_{1,i}, x_{2,i}, \ldots, x_{n,i}\}$ is the n-components vector of independent variables, $\boldsymbol{\beta} = \{\beta_1, \beta_2, \ldots, \beta_n\}$ is the n-components vector of parameters (to be estimated), μ_i are threshold values for the m ordered classes (to be estimated). Therefore, the parameters to be estimated are $n + m - 1$ (one of the threshold values can be fixed as reference point, i.e. $\mu_0 = 0$). Fig. 1 provides a graphical representation of the model described in Equation (1).

Since y_i^* is not a deterministic quantity, it is only possible to define the probability that the i individual selects the y ordered value.

$$P_i(y|\boldsymbol{\beta}) = P\left(\mu_{y-1} < y_i^* < \mu_y\right) = L\left(\mu_y - \boldsymbol{\beta}\cdot\boldsymbol{x_i}\right) - L\left(\mu_{y-1} - \boldsymbol{\beta}\cdot\boldsymbol{x_i}\right); \quad \mathrm{y} = 0, \ldots, \mathrm{m} \tag{2}$$