



## Following the crowd or avoiding it? Empirical investigation of imitative behaviour in emergency escape of human crowds



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When humans escape from a threat in a crowded space, how do they choose the best wayfinding strategy for their survival? This is a decision context in which individuals are heavily exposed to the actions of others; it is thus plausible to assume that they are influenced by the social interactions. It has been suggested by some influential theoretical studies that in emergency escape situations, ‘people show a tendency towards mass behaviour, that is, to do what other people do’ (Helbing, D., Farkas, I., Vicsek, T., 2000. Simulating dynamical features of escape panic. *Nature*, 407, 487–490, page 487). However, the validity of this assumption has not come under scrutiny, nor has the role of context-specific factors that may strengthen or weaken the possibility of displaying the so-called herd-type (or imitative) behaviour been adequately understood in this context. Here, we report on novel wayfinding decision experiments that simulated the escape of human crowds from multi-exit spaces. Participants’ perceptions of different contributing factors were quantitatively inferred from their observed choices ( $N = 3015$ ) using econometric modelling methods. Results showed that the direction at which the social interactions (i.e. observing the movements of other evacuees towards different exit alternatives) impacted on individuals’ navigational choices depended significantly on the decision maker’s knowledge about the attributes of the alternatives chosen by the crowd flows. Contrary to the conventional belief, people’s dominant wayfinding strategy was not to copy the escape directions that other people (i.e. the majority) chose. In fact, in a heavily crowded space with little or no choice uncertainty, observing many people choosing a certain exit direction reduced the desirability of that escape route. The assumption of herd-like behaviour does not necessarily apply to all contexts of evacuations and it should be considered in conjunction with the moderating role of context-specific factors, particularly the level of information available to individual evacuees.

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It has been shown by a great deal of research that social interactions and observing other people’s choices can influence our behaviour in many contexts of decision making (Baddeley, 2010). It has been established, particularly in economic and financial choice contexts (Hirshleifer & Hong Teoh, 2003; Kim, Yoon, & Kim, 2004; Kukacka & Barunik, 2013; Manahov & Hudson, 2013), that accessing knowledge about the decisions of others at an aggregate or a disaggregate level can impact on how we evaluate the available alternatives for our decision making (Muchnik, Aral, & Taylor, 2013) or how we perceive risks associated with our decisions (Moussaïd, 2013; Moussaïd, Brighton, & Gaissmaier, 2015; Suzuki, Jensen, Bossaerts, & O’Doherty, 2016), and it can also bias our opinions and judgements (Mavrodiev, Tessone, & Schweitzer, 2013; Moussaïd, Kämmer, Analytis, & Neth, 2013). This widely

observed phenomenon, which has been observed to be shared between collective systems of humans and animals (Arganda, Pérez-Escudero, & de Polavieja, 2012), is often referred to in the literature as herd behaviour (Raafat, Chater, & Frith, 2009; Rook, 2006) or behavioural contagion (Caetano & Yoneyama, 2011; Suzuki et al., 2016). Humans’ and animals’ decisions, particularly in uncertain environments where the properties of all possible options are not perfectly known by the decision makers, are often influenced by observing the choice of other individuals (Arganda et al., 2012).

It has been suggested that the effect of herd behaviour on the optimality of decisions, knowledge and perceptions can range from beneficial to detrimental (Farrell, 2011; Teraji, 2003) depending on the context (particularly the ratio of resource allocation for the situations in which agents compete for limited resources, Zhao et al., 2011). The phenomenon has also been recognized as a major source of suboptimal market outcomes such as volatility and

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clustering (Wagner, 2003), or aggravated financial inequalities (Muchnik et al., 2013). Previous studies have also shown that it has the potential to distort to significant degrees the beliefs and wisdom of the crowd (Lorenz, Rauhut, Schweitzer, & Helbing, 2011) in a variety of social contexts.

The phenomenon of social interaction has also received considerable attention in relation to the behaviour of foraging or migrating animals (Couzin, Krause, Franks, & Levin, 2005) as well as human groups on the move (Faria, Codling, Dyer, Trillmich, & Krause, 2009; Faria, Dyer, Tosh, Krause, 2010), particularly from the perspective of consensus decision making for decision contexts that require coordination or synchronization of individuals' actions (Boos, Pritz, Lange, & Belz, 2014; Dyer et al., 2008; Dyer, Johansson, Helbing, Couzin, Krause, 2009). The existing evidence has strongly suggested that information about individuals with pertinent knowledge (of food, resources or spatial targets) can be transferred among moving groups based on the visual perception of the local movements of others, even without obvious signalling or active communication (Faria et al., 2010). Individuals have the ability to identify and follow those who possess accurate information in the group and thus a group of informed minority has the capacity to lead the entire group to the target (Dyer et al., 2009).

Similar questions can therefore be raised about the potential role of social influence when a crowd of humans face a threat and must escape an environment that offers them multiple exit route options requiring them to make navigational decisions. Is escaping a threat a decision scenario in which our follow-the-crowd instinct comes to play? Clearly, in this context individuals are heavily exposed to the actions of others mainly through the visual perception of the local movements. Also, because of the sudden rush of occupants to escape routes in such scenarios, available exit capacities (per individual) might drop significantly and from this perspective the problem can also be viewed in the context of many agents competing for limited resources (here, capacities). However, it is not fully understood whether individuals tend to adopt herd-type behaviour in emergency escape scenarios as the optimum strategy for their survival.

Influential theoretical studies have suggested, however, that during emergencies 'people show a tendency towards mass behaviour, that is, to do what other people do' (Helbing, Farkas, & Vicsek, 2000, page 487). This theoretical assumption has also exerted a significant influence as a default behavioural rule (Bohannon, 2005; Low, 2000) on a number of methodological studies that have developed simulation models of crowd motion (Lu, Luh, Marsh, Gifford, & Tucker, 2014; Ma, Yuen, & Lee, 2016; Shiwakoti, Sarvi, Rose, & Burd, 2011; Song et al., 2013; Zheng & Cheng, 2011). Only a few experimental studies have been reported on this topic since this follow-the-crowd assumption was suggested in the literature, and these have predominantly been based on observations on escaping ants (Altshuler et al., 2005; Dias, 2015; Dias, Sarvi, Shiwakoti, Ejtemai, & Burd, 2013; Shahhoseini, Sarvi, & Saberi, 2016; Wang, Lv, & Song, 2015b) or mice (Lin et al., 2016; Saloma & Perez, 2007; Saloma, Perez, Gavile, Ick-Joson, Palmes-Saloma, 2015; Saloma, Perez, Tapang, Lim, & Palmes-Saloma, 2003). Using ants as models of panicking humans, Altshuler et al. (2005) found that ants make a more symmetrical use of exits in a 'high panic' escape situation than in a 'low panic' one. The use of panicked ants as a reliable model of humans' behaviour in escape situations has, however, been recently criticized by some authors (Boari, Josens, & Parisi, 2013; Parisi, Soria, & Josens, 2015) who observed behavioural features (even at aggregate level) that cannot be reasonably generalized to humans. It is believed that reliance on the ants or mice models as proxies of humans' escape emerges primarily from the challenges involved in designing and administering realistic human experiments at

reasonable costs that meet the ethical requirements of the experimentation (in terms of preventing harm to participants) at the same time (Haghani & Sarvi, 2016c).

Contrasting panicking ants or mice with the collective movements of humans leads us to suggest that conclusive generalizations about how humans escape a threat can hardly be drawn from the existing evidence, owing to their major contextual differences. An emergency escape essentially does not require any coordination or synchronization of actions as assumed in consensus decision-making scenarios. Decisions can be made by the agents individually without any consensus being reached as to the best possible directional choice.

To our knowledge, the assumption of imitative behaviour in escaping humans has not been validated based on solid empirical evidence. The assumption, however, has mainly been justified in methodological applications by attributing herd behaviour to the so-called state of 'panic' in emergency scenarios (Helbing, Farkas, & Vicsek, 2002; Helbing & Johansson, 2011; Lin et al., 2016; Parisi & Dorso, 2006; Saloma et al., 2003; Wang, Zhang, Shi, Yang, & Hu, 2015a). Although the literature on this particular topic does not offer a clear definition that is generally agreed upon, it has often been referred to as the 'breakdown of ordered, cooperative behaviour of individuals due to anxious reactions to a certain event' (Helbing & Johansson, 2011, page 697). In contrast, an emerging body of literature has recently revisited the conventional belief of irrational and panic-type behaviour (Cocking, Drury, & Reicher, 2009; Fahy, Proulx, & Aiman, 2012; Mawson, 2005; Quarantelli, 2008) in emergencies. It suggests that, rather than displaying indecision or erratic behaviour, humans do cooperate with other individuals and make reasonably predictable trade-offs to make the optimum decision in the light of the available information even in acute states of emergency (Kuligowski & Mileti, 2009; Li, Huang, Zhang, & Ni, 2016; Sherman, Peyrot, Magda, & Gershon, 2011; Still, 2014). Yet, to our knowledge, whether the state of anxiousness or fear can particularly strengthen a follow-the-majority instinct in humans has not been demonstrated.

More recently, some experimental studies in which wayfinding decisions of evacuees in crowded spaces were investigated found no evidence of herd-type behaviour. These studies, however, mainly included hypothetical decision experiments with virtual crowds (Bode & Codling, 2013; Bode, Wagoum, & Codling, 2014, 2015; Duives & Mahmassani, 2012; Haghani & Sarvi, 2016a; Haghani, Sarvi, Ejtemai, Burd, & Sobhani, 2015a; Haghani, Sarvi, & Shahhoseini, 2015b) which face the traditional question of generalizability (Chang, Lusk, & Norwood, 2009; Herbst & Mas, 2015; Levitt & List, 2007) and transferability to the context that they intend to address, also known as contextual (or hypothetical) bias (Hensher, 2010). It can be argued that since participants in these experiments do not realistically interact with other individuals as they do in actual evacuation scenarios, then their results might not perfectly represent their true behaviour.

Here, we revisit this assumption based on a large number of empirical observations extracted from the individual level analysis of a series of innovative experiments in which the emergency escape of human crowds was simulated in action. We examined the impact of social interactions on wayfinding decisions in conjunction with the physical factors of the escape environment such as spatial distances and target visibility. Individuals' perception and evaluation of these factors were quantitatively inferred from their observed decisions using econometric choice modelling techniques. We were particularly interested in testing whether introducing ambiguity in terms of the attributes of different escape route alternatives would significantly impact on how humans perceive the decisions of others observed to have chosen those alternatives. In other words, we aimed to investigate on a

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