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Stated and revealed exit choices of pedestrian crowd evacuees



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ABSTRACT

Introduction: Understanding fundamental behavioural features regulating the escape wayfinding decisions of pedestrian humans in built environments has major implications for the safety planning and the risk-analysis of crowded public facilities. In contrast to the vast interest invested in modelling the momentary responses of evacuees to their immediate surroundings (i.e. the collision-avoidance models), their global navigation behaviour is poorly understood albeit believed to be a major determinant of the accuracy of the crowd simulation models. The primary challenge arises from the scarcity of reliable data suitable for modelling purposes causing the experimental knowledge in the field lagging substantially behind the corresponding model developments. Observations derived from fully natural emergency contexts (in the form of modelling material) are rare and collecting data in realistic experimental settings poses its own major challenges. Only few experimental modelling attempts have been reported thus far in relation with this problem primarily using the stated-choice (SC) methods. Modelling based on revealed choices (RC), however, has remained absent in this context leaving the findings of the SC experiments mostly unverified. It is still unclear whether we can reliably learn from the wayfinding choices made in virtually visualised environments without the decision-makers interacting with real individuals and the physical elements of the environment as they do in the real-world settings. Furthermore, the extent to which the findings of these experiments are specific to the particular characteristics of the environment visualised in the experiments is also unclear.

Methods: To bridge this gap, here we report on discrete-choice estimates derived from observations of both types. Three datasets of stated exit choices (4958 observations) were collected through face-to-face interviews with pedestrians in three public places with the experiments referring to the particular geometry of the place in which the participants were interviewed. Also, 3015 disaggregate real (or more precisely, “realistic”) exit choices were extracted through individual-level video analysis of the footage of a series of novel evacuation trials that simulate pedestrians’ emergency escape. The participants competed and interacted with real individuals in an actual crowd and made actual wayfinding decisions to make the quickest possible escape. Our particular interest was investigating the sample-to-sample variations and the context-dependence of the inferred estimates.

Results: We observed fairly similar parameter estimate patterns emerged from all four datasets, and identified many behavioural aspects upon which all models consistently agreed regardless of their context of origin. Moreover, despite the significant differences

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between the parameter scales of the four models, the SC-generated models made predictions that were reasonably similar to those of the RC model as well as to those of the model derived from the combined data.

Applications: Our findings provide promising evidence as to the potential applicability of the SC methods in particular as well as other forms of virtual-reality decision experiments in general as a practical, flexible and ethical approach for the continuation of research and advancing the state of knowledge in this field.

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1. Introduction

The growing urban populations as well as the increasing occurrence of public events have given rise to a rapid rise in the frequency and the scale of congregations of large numbers of pedestrian humans in public spaces. Recent disastrous incidents have shown that crowded places can be exposed to significant safety dangers and that the presence of a large number of pedestrians can potentially result in injuries and fatalities at large scales if not planned and managed reasonably (Helbing et al., 2002; Helbing et al., 2007; Still, 2014). This has raised concerns as to the safety of crowded public facilities and has led to a growing body of research in various disciplines attempting to understand different aspects of human crowds and predict their behaviour in different situations and scenarios. Enhancing the state of knowledge about humans' behaviour in crowded spaces (in both emergency and non-emergency situations) is a necessary step towards the development of reliable modelling tools (Cheung and Lam, 1998; Daamen et al., 2005; Do et al., 2016; Kneidl and Borrmann, 2011; Kneidl et al., 2013). It will enable planners to perform reliable risk-analyses on the design and performance of their facilities, thereby improving the occupants' safety through taking effective planning or design measures.

There are several aspects of the problem that pose serious modelling challenges to the researchers. Among those is the context dependence of the emergent behaviour and the variety of contexts with which the modeller need to deal. Crowds can form at different sizes and for different purposes and activities such as sport events, political protests, religious gatherings, or they could simply form as a result of the rush of demand to public transport facilities and public buildings in peak hours. Also, from a spatial point of view, there is a large variety of geometric types in which crowds can be formed ranging from confined rooms to large open spaces, and to complex built environments or high-rise buildings. Clearly, each of these aspects and their various possible combinations can significantly impact on how the crowd may behave and thus necessitates dedicated modelling and empirical observations. This has made prescription of a universal crowd model that embodies all these aspects extremely challenging, if not impossible.

One particular topic that has received an increasing attention in the recent years is the escape and evacuations of pedestrian crowds when emergencies arise in complex built environments (Guo et al., 2011). The problem is of crucial importance and has major safety-related implications. However, realistic observations obtained from the real-world emergency contexts that can serve as modelling material are extremely rare (Haghani et al., 2014; Haghani and Sarvi, 2016c; Shahhoseini et al., 2016). On the other hand, owing to the intrinsic complexity and diversity of the human behaviour as well as the particular behavioural features that might arise during emergencies, pure modelling intuition is not likely to provide a sufficient answer to the problem, and this highlights the importance of empirical experimentation in this context.

Here, we focus on escape behaviour of pedestrian humans when emergencies arise in complex confined spaces. We mainly focus on situations where evacuees are subject to non-trivial navigational decisions stemmed from the sudden rush of the crowd and the drop of capacities at exit route options. There have been a number of studies attempted to model this problem based on empirical evidence among which stated-choice (SC) methods (Duives and Mahmassani, 2012; Haghani and Sarvi, 2016a; Haghani et al., 2015a; Haghani et al., 2015b; Lovreglio et al., 2014) or experimentations in virtual decision environments (Bode et al., 2014; Bode and Codling, 2013; Kinateder et al., 2014a; Kinateder et al., 2014b; Moussaïd et al., 2016) have proved as a popular and practical approach. In this class of studies, participants have been introduced to virtually visualised scenarios of emergency escapes from crowded places and have asked to make wayfinding (e.g. exit) decisions. However, taking into account the particular contextual elements presented by the real evacuations that are mostly failed to be represented in SC settings, major concerns can be expressed as to the reliability of findings obtained from the SC experiments in this context. This has left the applicability of the SC-generated exit-choice models unverified and subject to scepticism thus far. The absence of the revealed-choice (RC) observations, through which this question can be objectively investigated, has remained as a major research gap in this context despite the clear implications of this problem for the continuation of the research in this area. Moreover, it is not clear the extent to which the findings emerged from these SC experiments are specific to the particular geometrical features of the environments visualised in these experiments.

Here, we intend to address this problem by providing choice observations of both kinds. We conducted experiments of stated emergency exit choice by interviewing participants in public places as they left those places. As opposed to the common approach of the internet-based surveys, our choice experiments make partial references to the individuals' recent real-life decision merely on the account of the particular geometry visualised in the choice scenarios. We conducted this

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