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The Influence of National Culture on Evacuation Response Behaviour and Time: An Agent-Based Approach

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Abstract. "How does culture, in combination with cues, settings and affiliation, influence response-phase behaviour and time and total evacuation time?". A questionnaire and an agent-based model for a case study of a library evacuation in Czech Republic, Poland, Turkey and the UK have been developed to answer this question. Our questionnaire, conducted among 442 respondents (N = 105 from Czech Republic, N = 106 from Poland, N = 106 from Turkey and N = 125 from the United Kingdom), shows significant differences in the number of performed response tasks per culture - whereby Turkish respondents perform the most response tasks and British the least - and the results were directly implemented in our agent-based model. Simulation results show: (1) these differences - in combination with emergent effects for task choice and agent interactions - directly translate into the average response and evacuation times being highest for Turkey, followed by Poland, Czech Republic, and the UK, (2) cues, setting and affiliation influence response and evacuation time - such as being informed by staff giving a negative correlation and evacuating in groups a positive correlation with response time -, while the magnitude of these effects differ per culture. Our results suggest that faster response times might be related to dimensions of national culture, such as weak uncertainty avoidance and high individualism.

Keywords: Evacuation response behaviour · Agent-based model · Cross-cultural · Evacuation modelling

1 Introduction

The behaviour of building occupants is one of the most critical determinants for successful fire evacuations [10,20]. The understanding of occupant behaviour can

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be used to make informed policy decisions, support emergency relief efforts and help with facilitating building design and developing public emergency education [15].

Building fire evacuation behaviour consists of two major phases: the response and the evacuation movement phase [8]. During the response phase, an occupant is notified of unusual happenings, after which an occupant performs tasks to validate what is happening and to prepare for evacuation movement. The response phase is followed by the evacuation movement phase, during which an occupant performs purposeful movement towards an exit or a place of safety.

Response phase tasks can be of two kinds. Action tasks "involves the occupant physically undertaking an activity such as: shutting down a work station; packing work items; moving to another location, etc." [7] and Information tasks "involves the occupant seeking, providing or exchanging information concerning the incident or required course of action." [7]. The duration of the response phase is referred to as the response time. While incident analyses have shown a connection between the response time and the number of fatalities [10], response-phase research has been frequently ignored or oversimplified [28]. The duration of the response phase and the evacuation movement phase together form the total evacuation time.

Three important factors influence response-phase behaviour: cues, setting, and affiliation [18]. A cue in this context is described as "a change in the environment indicating something wrong or different from usual" [25], setting refers to the location and surroundings of an occupant [21], while affiliation refers to people with whom an occupant is connected during the evacuation, such as family or friends [25].

Cues come from different sources: from the fire itself (flames, smoke), warning systems (alarm, light flashes) and other people (occupants, firefighters) [2]. Building occupants go through an extensive decision-making process in which they continuously receive different information from cues, process this information, solicit additional information if necessary, and take actions accordingly [16].

The types of cues an occupant receives are highly dependent upon the occupant's setting. The theory of occupancy [24], represents the setting as "the constraints on, conditions and possibilities of knowledge and actions afforded by the social, organisational and physical locations occupied by people over time" [21]. According to this theory, the setting may influence how an occupant behaves. Herein the social context plays a role. For example, an occupant will not be able to speak to others when there is no one around.

Besides the environmental setting of an occupant, affiliation is of influence. According to the theory of affiliation [25], people have the tendency to seek the familiar in uncertain situations, as they feel safer in a known environment. Many building occupants tend to seek their friends and relatives before starting evacuation, causing high delays [23].

Besides the cues, setting and affiliation, culture influences building fire behaviour [8,19]. Culture is defined as "the collective programming of the mind

distinguishing the members of one group or category of people from others" [9]. Culture can be found anywhere and can be of multiple forms, from organisational cultures to cultures within social classes and cultures associated with religion [3]. For this study, culture is defined as national culture. As exposure to a new homeland could modify or override ones organic cultural influences [17], in this paper we focus on national culture: the culture of people with the same nationality, living in the same country. National culture can be described by Hofstede's six cultural dimensions: Power Distance, Individualism, Masculinity, Uncertainty Avoidance, Long Term Orientation and Indulgence [9]. For each of the dimensions, values can be allocated to a population to describe the norms and values and behaviour of that population. Out of a maximum score of 100, UK scores the lowest on uncertainty avoidance (35 for UK versus Czech Republic (74), Turkey (85) and Poland (93)), but the highest on Individualism (89 for UK versus Czech Republic (58), Poland (60) and Turkey (37) [9]). Most evacuation research is executed for countries with similar cultural backgrounds: UK, USA, Canada, Australia and New Zealand [7]. There is little research available on the effect of culture on evacuation behaviour for other countries, nor is there data available. Due to this lack of research, the same evacuation data is frequently used to provide evacuation insights within very different cultures [7]. However, findings from one country cannot be applied directly to others, as the few cross-cultural studies performed, have shown significant influences of culture on evacuation behaviour. Cross-cultural studies have shown how culture influences levels of emotions during an evacuation [1] and tendencies to evacuate [13]. Furthermore, studies have shown how culture influences personal space [22] and walking speed [14]. Additionally, the BeSeCu project [7], found that culture influences the number of tasks performed during the response phase of an evacuation. During this project, 4 unannounced evacuation drills took place in Czech Republic, Poland, Turkey and the UK. This project measured the number of response tasks performed, as well as the response and evacuation times. However, the project did not take into account the types of response tasks performed and their interactions with other influential factors. This inspired us for the setup of our study.

As culture, cues, setting and affiliation have been shown to influence response-phase behaviour [7,18], our study explores the potential effects of their interactions on response-phase behaviour and response and evacuation time. Therefore, our main research question is: "How does culture, in combination with cues, settings and affiliation, influence response time and total evacuation time?".

To answer the research question, an agent-based model has been developed based on a case study on library evacuation in Czech Republic, Poland, Turkey and the UK [7], together with literature research and knowledge acquired through a questionnaire administered (online) in each of these countries. Our questionnaire results - type and order of response phase tasks - have been directly translated into model input, to simulate detailed evacuation behaviours of library visitors during a fire incident. The behaviour of library staff is considered to be

culture-independent, as staff behaviour could be largely affected by the types of training that they have had [5].

The rest of this paper is organised as follows. Section 2 addresses the questionnaire results and the model setup. Section 3 shows the model results. Section 4 discusses the results, strengths, weaknesses, implications, future research and ends with a conclusion.

2 Methods

Empirical evacuation experiments are often costly and labour intensive. This paper takes an agent-based modelling and simulation approach with the aim to understand response phase behaviours themselves and their effects on response and evacuation time. Agent-based models provide the ability to implement social structures and to capture emergent phenomena. The input of our model and the agent behaviours modelled are based on a literature review and our questionnaire study results [26], summarised below. Then, the model is explained.

2.1 Case Study Contextualisation

As described above, the case-study considers four national cultures: Czech Republic, Poland, Turkey and the UK. A library evacuation is chosen as this situation is considered to be similar for all countries. First of all, library buildings in the four countries are expected to be similar and building occupants are expected to have similar demographics. Furthermore the types of activities performed in the libraries are of a similar nature.

The case-study considers a fire in the library. All staff members and visitors hear a fire alarm. This alarm contains a voice message announcing an emergency in the building and that everyone needs to leave the building. This is followed by an alarm tone. The cues, setting and affiliation that can influence the situation and behaviour of the building visitors are described in Table 1.

2.2 Questionnaire Results Used for Model Input and Agent Behaviours

A total of 20 response tasks (9 information and 11 action tasks) were identified for a library evacuation on the basis of a literature review [26], see Table 2. Participants were asked which tasks and in which order they would perform these tasks for a series of scenarios; within which cues, setting and affiliation also played a role. The questionnaire was translated into the native languages of the respondents. The inclusion criteria for the respondents were: age (18–40 years old), their residency and nationality (both from the same country), and experience with visiting a public library at least once.

Table 1. Implementation of culture, cues, setting and affiliation

Influential factor	Implementation
Culture	National culture implemented through 4 countries: Czech Republic, Poland, Turkey and the UK.
Cues (2 types)	(1) Being informed by a staff member: A staff member tells a visitor that there is an emergency and that the visitor needs to leave the building as quickly as possible. (2) Seeing signs of fire and/or smoke.
Setting	Being surrounded by others (anyone present within a distance of 20 m) or being in a closed off space/not nearby others.
Affiliation	Small groups of two coworkers/friends present in the building. These two people can be together or separated in space at any point in time.

Data analysis was performed for 442 participants (217 females; 220 males; 5 other), with N = 105 from Czech Republic, N = 106 from Poland, N = 106 from Turkey and N = 125 from the United Kingdom. The main results include significant differences in the total number of tasks reported, this was found by performing a one-way ANOVA test ($F(3.416) = 8.888$; $p = 0.000$). Respondents from Turkey perform the highest number of tasks ($M = 5.42$, $SD = 2.82$), followed in decreasing order by Poland ($M = 5.05$, $SD = 2.08$), Czech Republic ($M = 4.54$, $SD = 2.18$), and the UK ($M = 3.86$, $SD = 2.14$). Secondly, the study showed that more information tasks than action tasks are reported for all countries. Thirdly, response behaviour in all countries is shown to be influenced by cues, setting and affiliation, as these influence the number of tasks performed and the types of tasks performed. The influence of the cues, setting and affiliation on response behaviour differs per country [26]. For example, probabilities

Table 2. Identified information and action tasks in a library situation [26]

Information tasks	Action tasks
Phone someone to seek information	Shut down workstation, lock files, tidy desk etc.
Engage with electronic media to seek information	Pack personal and work items in close vicinity
Seek information through conversations with other people nearby	Collect and put on coat
Move to another location to seek information	Change footwear/glasses/clothing
Look around and listen to what is happening	Physically assist others
Seek information through professional bodies	Collect emergency equipment
Phone someone to provide information	Move to another location to collect personal/work items
Actively provide information and/or instructions to others nearby	Move to another location to find friends/coworkers
Actively search for others in the building, to inform them	Wait for a friend/coworker to leave
	Call alarm number
	Fight fire

for collecting belongings decreases after seeing fire, however these probabilities decrease with 21% for the UK, while these decrease with only 10% for Poland.

2.3 Agent-Based Evacuation Model Including National Cultures

An agent-based model was designed and implemented in NetLogo as follows.

Agents. The model consists of two types of agents: visitors and staff members of a library. Visitors are people who do not perform official work at the library and staff members are people who do perform work in the library on a regular basis. Visitors and staff members perform different behaviours based on the rule-role model [6]. Staff members all perform similar behaviour for each culture, as the behaviour of library staff could be largely affected by the types of training that they have had [5]. The behaviour of the visitors is culture dependent in line with [26].

Environment. A library was chosen as a common environment inspired by [7]. The model represents a two-dimensional space, based on a floor plan from the ground floor of Delft University of Technology's Library, see Fig. 1. In NetLogo, the floor plan consists of 200 by 190 patches, with each patch representing an area of 2 by 2 m.

The patches are coloured in one of seven colours, with each colour representing specific characteristics. *Black* patches represent walls inside the building or areas outside the building. These patches are not accessible by agents. *Red* patches represent exits of the building. *Blue* patches indicate areas where sitting places are located. *Lilac* patches indicate areas which are closed offices, in which only one person can sit at a time. *Orange and yellow* indicate fire. Patches only

Fig. 1. Floor plan of the TU Delft library as used in the model

colour orange or yellow, whenever a fire occurred within the building. As this area is dangerous, agents are not able to access these patches. Finally, *White* patches represent all other patches inside the building, that are not represented by any of the colours above.

Evacuation Behaviour. All of the building occupants go through the following four phases: Normal phase, Response phase, Evacuating phase and Evacuated phase. During the Normal phase, agents are not aware of any unusual happenings. During the Response phase, agents receive the first cues of the fire and search for information and prepare for evacuation. The agents perform purposeful movement towards an exit during the Evacuating phase and they reach the Evacuated phase whenever they have reached an exit in the library. Additionally, agents interact with their environments through communication with visitors and staff members, through observations and avoidance of fire, obstacles and other agents, through signals of a fire alarm and connections with friends and/or colleagues. As the focus of this research is on the Response phase, cultural aspects are considered in this phase only.

Response Phase Behaviour. Generally, three methodologies can be identified for simulating occupant behaviour during the response phase [12]. One method is to assign a time of delay to account for any actions that might be performed during the response phase by an individual, occupants remain stationary in their position, until they start moving towards an exit [11]. In the second method, building occupants are assigned a specific behavioural itinerary or a specific task. A specific time has been assigned for performing each of these tasks. The building occupant performs his/her itinerary actions, before starting the evacuation movement. The third method uses a predictive-style model, where one particular type of cue influences a particular type of evacuation behaviour. Examples of such cue-behaviour linkages are: presence of exit signage leading to choice of a specific evacuation route and smoke obscuration level influencing exit choices [11].

In our model, the second and third method are combined. The occupants have an itinerary and execute these tasks, however, cues and affiliation cause adjustments in the itinerary. The process is shown in Fig. 2.

The response phase decision-making of a visitor consists of three parts: the initial response tasks, adjustment of response tasks due to cues and setting and finalising response tasks. Visitors execute all of their itinerary tasks in the given sequence until they are all finished. Whenever another occupant approaches them to ask something or provide information, they will pause performance of their tasks for the time duration of this conversation. For the model, all 20 response tasks have been modelled separately and in detail. For example, for the task "Seek information through professional bodies" (depicted in Fig. 3), a visitor will look/walk around to see if there is a staff member nearby. If there is a staff member nearby, the visitor will walk towards the staff member. They will both remain together for a few seconds, during which the staff member will inform

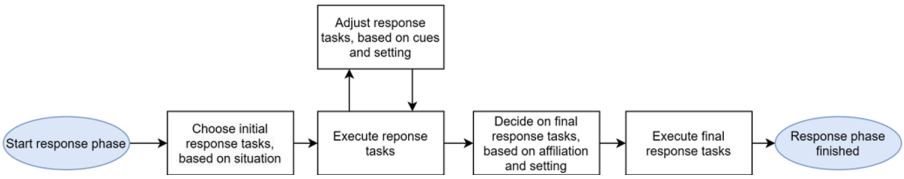

Fig. 2. Response phase decision-making of visitors

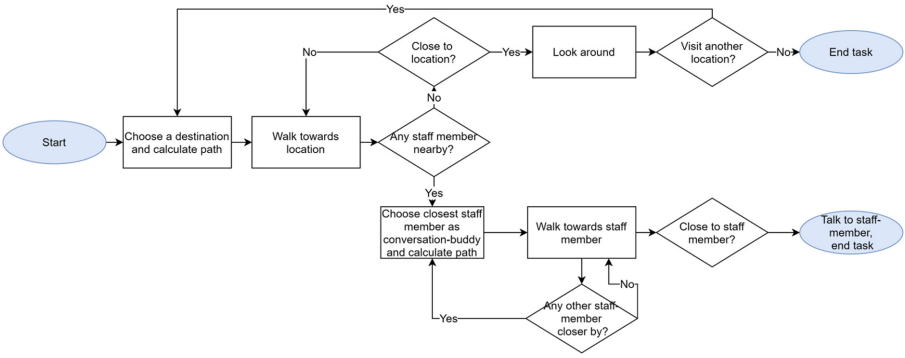

Fig. 3. Process "Seek information through professional bodies"

the visitor to evacuate as quickly as possible. Afterwards, they both continue with the rest of their itinerary.

A visitor's initial response itinerary is dependent on the cues received before the start of the response phase and the setting. Two types of cues are considered: signs of smoke or fire and being informed by a staff member. The setting can be either one in which there are other occupants in nearby surroundings or one in which there are not. By combining these cues and settings, multiple situations arise. For each situation, a probability tree developed based on the questionnaire data, determines the response itinerary to be performed. The probability trees indicate probabilities for which tasks are to be performed in which sequence. Through randomisation, an initial itinerary for the visitor will be selected from the probability tree.

Different factors can influence execution of a building occupant's itinerary. Firstly, the two types of cues involved are of influence: signs of smoke and/or fire and being informed by a staff member. The questionnaire data is used to alter the tasks not executed yet. This means that there are certain chances that an occupant may remove tasks from his/her itinerary or that new tasks, not initially included in the itinerary, will be added to the itinerary. Additionally, the setting influences an agent's choice to perform tasks related to location. For example, when the itinerary states that an occupant will collect his/her coat, the choice to do so may depend on the location of the agent. An extra decision

process on whether to move to the location or not may be needed if the coat is not close to the occupant.

After finalising the previously defined itinerary, there is a possibility that more tasks will be added. Firstly, if a building occupant has not executed any tasks concerning his/her belongings, there is a possibility to pick these up after finishing all tasks. Secondly, if a building occupant is in the library together with a friend or colleague, he/she must decide to search/wait for this friend, or not.

After all response tasks have been finished, the Evacuation phase starts. The full model and model overview can be downloaded from GitHub [27].

2.4 Model Validation

The model results were validated against the empirical results of the BeSeCu project [7], figures used for the comparison can be found in [27].

The comparison of our model results and the empirical BeSeCu results [7] show similar patterns for the response time distributions and the number of people evacuated over time. However, different orders of magnitude for the response and evacuation times were detected. This can be explained by the following two reasons. Firstly, participants in the BeSeCu project could repeat response tasks, while in our model this was not possible as repetitions could not be measured by the questionnaire software used. Secondly, our model uses similar notification times for all countries, as there is limited information available on cultural influences on notification times. For the BeSeCu project, however, the notification times differed per country. As it was not possible to validate the model with data other than that of the BeSeCu project [7], the obtained results should only be used within the context of this study. The overall model behaviour and the effect of influential factors do seem to align; however the exact quantitative outcomes have not been validated.

3 Results

3.1 Effects of Culture on Response and Total Evacuation Time

Figure 4 shows how the total evacuation times per country are made up of notification time, time used to perform response tasks and time used for evacuation movement. The response tasks take up most of the evacuation time (201–278 s), followed by movement time (150–156 s) and notification time (43–44 s). Interestingly, Czech Republic, Poland, Turkey and the UK differ on the response tasks time, while notification times are quite similar for all four countries. This indicates that differences between the countries in emergent response behaviour do not affect notification times.

The plots in Fig. 5, show response and evacuation time distributions per country. The average response time is highest in Turkey ($M = 290.79$, $SD = 24.27$), followed by Poland ($M = 262.79$, $SD = 20.48$), Czech Republic ($M = 234.80$, $SD = 14.39$) and the UK ($M = 214.02$, $SD = 34.63$). These times differ due to the

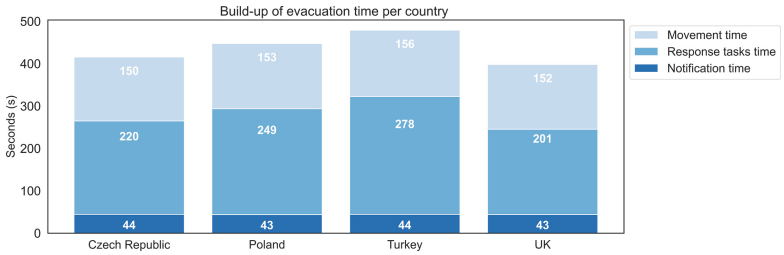

Fig. 4. Build-up of total evacuation time per culture

number of tasks performed per country and the types of tasks performed. Similarly, the average evacuation time is highest in Turkey (M = 416.79, SD = 28.98), followed by Poland (M = 385.13, SD = 29.93), Czech Republic (M = 355.60, SD = 15.37) and the UK (M = 336.39, SD = 19.90). One-way ANOVA analyses and post-hoc tests show significant differences for both response and evacuation times, between each of the four countries. These distributions relate to the model input for the total number of tasks performed. The UK performs fewer, and Turkey performs more, tasks than the other countries. Additionally, a larger spread for the number of tasks in Turkey was found compared to the Czech Republic, Poland, and the UK. This is directly translated into the response times.

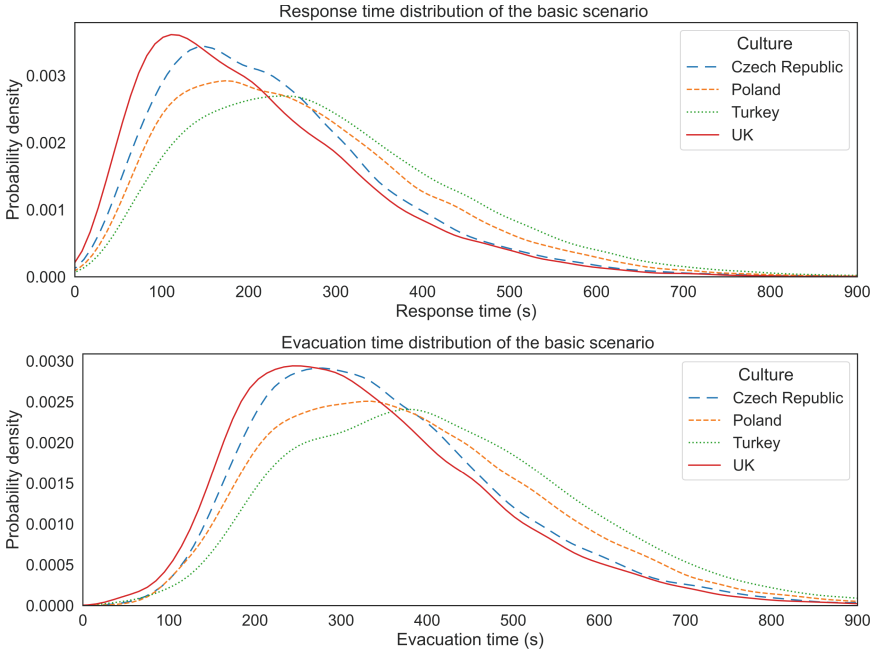

Fig. 5. Distributions of the response and evacuation times of all visitors

3.2 Effect of Cues, Setting and Affiliation on Response and Total Evacuation Time

Two cues were analysed: being informed by a staff member or seeing fire or smoke. Two settings were analysed: how does the chance of being in a closed off space/not around others influence the outcome? For affiliation, the number of friend/colleague groups in the building have been analysed. Correlations have been calculated for each influential factor (cue, setting, affiliation) in combination with each of the model outcomes (average response and evacuation time). Pearson's r correlation tests have been used to find out if these observed correlations are significant. An overview of all correlations is depicted in Table 3.

Table 3. Correlations between influential factors (cues, setting, affiliation) and model outcomes (average response or evacuation time) for each of the four countries (Czech Republic, Poland, Turkey, UK).

Influencing factor	Pearson r correlations between influencing factor and outcome variable			
	Czech Rep.	Poland	Turkey	UK
Model outcome: average response time				
Cue: Informed by staff	−0.5755**	−0.4820**	−0.4007**	−0.4365**
Cue: Fire Seen	0.2944**	0.2213**	0.2148**	0.1439*
Affiliation	0.7739**	0.7363**	0.7044**	0.7528**
Setting	0.1678**	0.0872	0.1034	0.1318*
Model outcome: average evacuation time				
Cue: Informed by staff	−0.5713**	−0.5326**	−0.4391**	−0.4744**
Cue: Fire Seen	0.2463**	0.2074**	0.2436**	0.1400
Affiliation	0.7058**	0.6862**	0.7034**	0.6946**
Setting	0.1356*	0.0581	0.1116*	0.1644**

Note. Significance: $*$ p $\leq$ 0.05, $**$ p $\leq$ 0.01

Cues. A negative correlation has been found between average response time and the percentage of people informed: average response times decrease as the percentage of people informed increases, see Fig. 7. This effect is highest for Czech Republic ($r = -0.58$, $p \leq 0.01$) and lowest for Turkey ($r = -0.4$, $p \leq 0.01$). These differences can be traced back to the model input, in which the Czech Republic has shown the highest decrease in the number of response tasks reported after being informed by a staff member. A similar influence of the cue on the average evacuation time is found. While the correlation stays the same for Czech Republic, there are slight increases for each of the other countries. This effect can be explained by a positive relationship that was found between the number of staff members in the building and the percentage of visitors informed

by a staff member. This effect levels out whenever the number of staff members in the building increases and a high percentage of the visitors is informed.

Response times slightly increase, for all countries, if more people have seen fire, see Fig. 6. This effect is highest for Czech Republic ($r = 0.29$, $p \leq 0.01$) and lowest for the UK ($r = 0.14$, $p \leq 0.05$). The cause of these higher response times cannot be traced back to the number of tasks performed after seeing the fire, to affiliative behaviour or to the collection of belongings. Therefore, it seems caused by changes in the types of tasks performed. All countries report a relatively high likelihood of calling the emergency number or fighting the fire. Both of these tasks take up a relatively large amount of time.

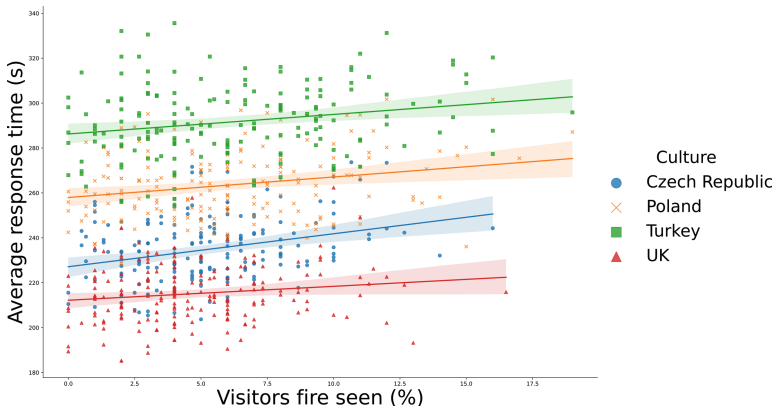

Fig. 6. The effect of seeing fire on average response time

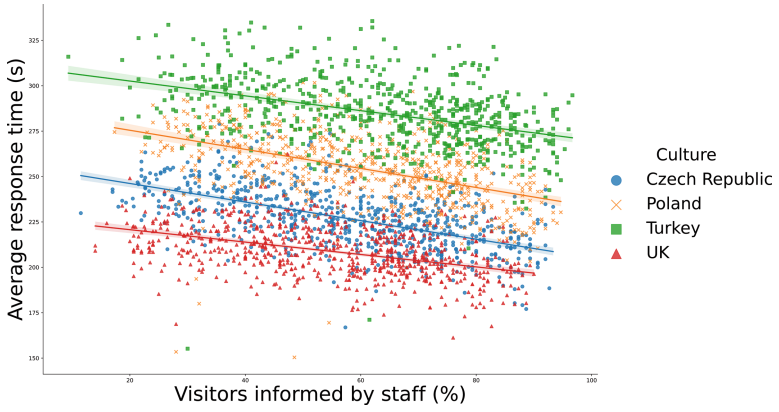

Fig. 7. The effect of being informed by a staff member on average response time

Setting. Small positive correlations between the setting and the average response time were found for Czech Republic ($r = 0.17$, $p \leq 0.01$) and the UK ($r = 0.13$, $p \leq 0.05$), while for Poland and Turkey, no significant correlations were found. What is noticeable, is how the response times differ less when 25 visitors are inside the building in comparison to more people inside the building.

It was expected that response times would decrease whenever more people are present in the building, because chances of being informed by another visitor, or seeing others evacuate, increase. However, this effect was not found thus it seems that the effects of the setting can be explained by clogging and the possibility to perform more response tasks.

Affiliation. Response times in Czech Republic, Poland, Turkey and the UK are all strongly influenced by affiliation. Response times increase whenever there are more friend groups in the building. Czech Republic is most influenced by this parameter ($r = 0.77$, $p \leq 0.01$) and Turkey the least influenced ($r = 0.70$, $p \leq 0.01$). The high effect on Czech visitors is related to the likelihood of showing affiliative behaviour, as found in the questionnaire. Similar are observable for the effect of affiliation on the average evacuation time.

4 Discussion and Conclusion

This study answered the following research question: *"How does culture, in combination with cues, settings and affiliation, influence response-phase behaviour and time and total evacuation time?"*.

The main finding is that the countries all have significantly different response and evacuation times. Simulation results indicate that Turkey is slowest during both the response phase and the total evacuation. This is followed by Poland, Czech Republic, and the UK. This order is similar to the order of the number of tasks reported in the questionnaire. It thus seems to be a direct result of the behavioural input (number of response tasks) used for the model in combination with emergent effects due to task choice and agent interactions, such as staff warning visitors and visitors evacuating in small groups. Combining the findings of the questionnaire and model shows that higher number of response tasks seem to lead to higher response times and total evacuation time. This corresponds with other evacuation research [4], that found that an increased number of tasks contributes to an increased response time. The model outcomes and the effect of different factors (cues, setting, affiliation) on the model outcomes seem valid at the level of "stylized facts". Exact quantitative outcomes have not been validated, and would not be expected to correspond, due to simplifications inherent in modelling. Although there were differences in the number of tasks performed and the notification times used in the BeSeCu project [7], the overall patterns in the response time distribution and the people evacuated over time generated by our model were similar to those of these empirical experiments.

The differences in response behaviours among the countries, found in the survey and simulation results, could be related with Hofstede's cultural dimension scores, however these are conjectures at this moment, as yet not confirmed

by empirical research. We speculate that UK showing the fastest response times might relate to the lower score on uncertainty avoidance and higher score on individualism versus the other three countries. According to [9], cultures with a high uncertainty avoidance tend to get more anxious in ambiguous situations. Our interpretation is that a weak uncertainty avoidance leads to performing less information tasks, and thus a faster response time for the UK versus the other countries. In individualist societies, people are expected to take care of themselves and not necessarily of the larger group [9]. We speculate that individualistic cultures might be less inclined to use communication or information gains during an evacuation, leading to faster response times for the UK, versus the other countries. Briefly said, a Brit is more likely to just go for it. Additionally, we speculate that collectivist cultures (of which Turkey is an example in our sample), are more likely to perform affiliative behaviour, which causes slower response times. A strength of this research is in the detail of the analysis in how response behaviour is influenced by cultures and how these cultural behaviours are affected by cues, setting and affiliation. No previous studies have combined these two aspects and especially not in as much detail as in this study. Additionally, the agent based model developed for this study is based on behavioural data, making the outcomes more powerful and reliable compared to other studies. This model could be applied to other environments, but also to other cultures and to include other factors that influence the Response phase.

Limitations of this research can be found in the simplification of evacuation behaviour, the method to collect behavioural data through a questionnaire and the limited knowledge available for modelling response tasks. Future research can cope with these limitations by extending this research with other factors that influence behaviour, conducting empirical evacuation experiments, and studying what behaviour is performed exactly during the different task types. Furthermore, future research poses opportunities for studying response behaviour in other cultures and environments, studying environments with mixed cultures and developing adequate evacuation policies.

Overall, this research provides a new approach and an agent-based model to study the effect of cultures, in combination with cues, setting and affiliation, on response-phase behaviour and response and evacuation times. Acknowledging the importance of cross-cultural research for evacuation behaviour adds value for policy makers and emergency planners. This research can be used as a starting point for discussions among safety practitioners and other stakeholders.

References

1. Almejmaj, M., Skorinko, J.L., Meacham, B.J.: The effects of cultural differences between the us and Saudi Arabia on emergency evacuation-analysis of self reported recogntion/reaction times and cognitive state. Case Stud. Fire Saf. **7**, 1–7 (2016). https://doi.org/10.1016/j.csfs.2016.12.002
2. Brennan, P.: Modelling cue recognition and pre-evacuation response. Fire Saf. Sci. **6**, 1029–1040 (2000). https://doi.org/10.3801/IAFSS.FSS.6-1029

3. Cohen, A.B.: Many forms of culture. Am. Psychol. **64**(3), 194–204 (2009). https://doi.org/10.1037/a0015308
4. Day, R.C., Hulse, L.M., Galea, E.R.: Response phase behaviours and response time predictors of the 9/11 world trade center evacuation. Fire Technol. **49**(3), 657–678 (2013). https://doi.org/10.1007/s10694-012-0282-9
5. Formolo, D., Bosse, T., van der Wal, N.: Studying the impact of trained staff on evacuation scenarios by agent-based simulation. In: Staab, S., Koltsova, O., Ignatov, D.I. (eds.) SocInfo 2018. LNCS, vol. 11186, pp. 85–96. Springer, Cham (2018). https://doi.org/10.1007/978-3-030-01159-8_8
6. Fridolf, K., Nilsson, D., Frantzich, H.: Fire evacuation in underground transportation systems: a review of accidents and empirical research. Fire Technol. **49**(2), 451–475 (2013). https://doi.org/10.1007/s10694-011-0217-x
7. Galea, E.R., Markus, S., Deere, S.J., Filippidis, L.: Investigating the impact of culture on evacuation response behaviour (2015)
8. Galea, E., Sharp, G., Deere, S., Filippidis, L.: Investigating the impact of culture on evacuation behavior - a Turkish data-set, vol. 10 (2012). https://doi.org/10.3801/IAFFS.FSS.10-709
9. Hofstede, G., Hofstede, G.J., Minkov, M.: Cultures and Organizations - Software of the Mind: Intercultural Cooperation and its Importance for Survival, 3rd edn. McGraw-Hill, New York (2010)
10. Kobes, M., Helsloot, I., Vries, D., Post, J.: Building safety and human behaviour in fire: a literature review. Fire Saf. J. **45**, 1–11 (2010). https://doi.org/10.1016/j.firesaf.2009.08.005
11. Kuligowski, E.: Predicting human behavior during fires. Fire Technol. **49**(1), 101–120 (2013). https://doi.org/10.1007/s10694-011-0245-6
12. Kuligowski, E.D., Peacock, R.D., Hoskins, B.L.: A Review of Building Evacuation Models; 2nd Edition. NIST Technical Note 1680, p. 36 (2010)
13. Lazo, J.K., Bostrom, A., Morss, R.E., Demuth, J.L., Lazrus, H.: Factors affecting hurricane evacuation intentions. Risk Anal. **35**(10), 1837–1857 (2015). https://doi.org/10.1111/risa.12407
14. Levine, R., Norenzayan, A.: The pace of life in 31 countries. J. Cross-cult. Psychol. **30**, 178–205 (1999). https://doi.org/10.1177/0022022199030002003
15. Lin, J., Zhu, R., Li, N., Becerik-Gerber, B.: Do people follow the crowd in building emergency evacuation? A cross-cultural immersive virtual reality-based study. Adv. Eng. Inf. **43**, 101040 (2020). https://doi.org/10.1016/j.aei.2020.101040
16. Lindell, M.K., Perry, R.W.: The protective action decision model: theoretical modifications and additional evidence. Risk Anal. **32**(4), 616–632 (2012). https://doi.org/10.1111/j.1539-6924.2011.01647.x
17. Litvin, S.: Cross-cultural research: are researchers better served by knowing respondents' country of birth, residence, or citizenship? J. Travel Res. **42**, 186–190 (2003). https://doi.org/10.1177/0047287503254955
18. Liu, Y., Zhang, Z., Mao, Z.: Analysis of influencing factors in pre-evacuation time using interpretive structural modeling. Saf. Sci. **128**, 104785 (2020). https://doi.org/10.1016/j.ssci.2020.104785
19. Matsumoto, D.: Culture, context, and behavior. J. Pers. **75**(6), 1285–1320 (2007). https://doi.org/10.1111/j.1467-6494.2007.00476.x
20. Pan, X., Han, C.S., Dauber, K., Law, K.H.: Human and social behavior in computational modeling and analysis of egress. Autom. Constr. **15**, 448–461 (2006). https://doi.org/10.1016/j.autcon.2005.06.006

21. Samochine, D.A., Boyce, K., Shields, J.: An investigation into staff behaviour in unannounced evacuations of retail stores - implications for training and fire safety engineering. In: Fire Safety Science, pp. 519–530 (2005).https://doi.org/10.3801/IAFSS.FSS.8-519
22. Samovar, L., Porter, R., McDaniel, E., Roy, C.: Communication Between Cultures. Cengage Learning, Boston (2016)
23. Sime, J.: Movement toward the familiar. Environ. Behav. **17**, 697–724 (1985)
24. Sime, J.: Understanding human behaviour in fires-an emerging theory of occupancy. University of Ulster Faculty of Engineering, School of the Built Environment, Fire Safety Engineering Research and Technology Marks and Spencer Guest Lecture, Ulster (1999)
25. Sime, J.D.: Affiliative behaviour during escape to building exits. J. Environ. Psychol. **3**(1), 21–41 (1983). https://doi.org/10.1016/S0272-4944(83)80019-X
26. Van Damme, E.R.I., van der Wal, C.N., Galea, E., Minkov, M.: Unpublished manuscript: the effect of national culture on evacuation task behaviour: a cross-cultural survey (2022)
27. Van Damme, E.: The influence of culture on evacuation response task behaviour: data and model (2021). https://github.com/elviravandamme/EvacuationResponseCulture
28. Vistnes, J., Grubits, S.J., He, Y.: A Stochastic approach to occupant pre-movement in fires. In: Fire Safety Science, pp. 531–542 (2005). https://doi.org/10.3801/IAFSS.FSS.8-531