

## AN ANALYSIS OF THE RECOGNITION AND RESPONSE BEHAVIOURS OF EVACUEES OF WTC 1 ON 9/11.

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### ABSTRACT

The terrorist attack on the World Trade Centre (WTC) in New York 2001 resulted in one of the largest full-scale evacuations of high rise buildings in modern times. The survivors' evacuation experiences provide valuable insights into the factors which influence egress in a rapidly changing high-rise building environment. Primary factors contributing to deaths from any fire is the delay in warning the occupants and the extended time lapses before escape movement actually commences. The primary focus of this paper is in relation to the *recognition and response* phases of a sample of 126 occupants of WTC1 on 9/11. It includes analysis of the cues received by evacuees and their subsequent response activities. The inter-relationships between these and other potential influencing factors including perception of risk, location within WTC1, prior evacuation experience (1993 evacuation) and individuals' roles and responsibilities are also explored. The results indicate that occupants performed many different activities, with evidence of differences in the activities of occupants on the upper, middle and lower floor clusters. The results also indicate a link between risk perception and the likelihood of performing certain activities, e.g., collecting belongings.

**KEYWORDS** WTC, high-rise evacuation, recognition, response, risk perception

### INTRODUCTION

It has long been recognised that a primary factor contributing to deaths from fire is the delay in warning occupants and extended times before movement commences. Previous work<sup>1,2</sup> suggests that the delay in starting positive evacuation actions can be much longer than the time to travel the distances to and through exits. Pre-evacuation activities have been documented in a number of papers and reports<sup>3,4</sup> and many studies have been designed to investigate the duration of the associated delay time in a range of different building types<sup>5,6,7,8</sup>. However, it is apparent that our understanding of human behaviour during this phase is insufficient and should be considered in relation to different contextual settings.

Several studies have already investigated the evacuation of the WTC using published accounts from survivors, questionnaires, interviews and focus groups<sup>9,10,11</sup>. The UK, ESRC funded, HEED project was conducted by the Universities of Greenwich, Ulster and Liverpool. Specifically it sought to capture and present the detailed and multifaceted behaviours and experiences of the evacuees of WTC towers 1 and 2 in a relational database which would facilitate research towards the design, construction and use of safer built environments. Detailed accounts of the methodologies employed in the HEED project have been presented previously<sup>12,13</sup>. In essence the study comprised:

- a *Pre-interview Questionnaire* designed to extract basic factual information from the participant, including information related to the participant's sex, age, pre-existing medical health, knowledge of the layout of the WTC, whether they had a fire safety role, fire safety training received etc,

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- a *Free flow narrative* where each participant was encouraged and assisted to recall the morning of 9/11 and then to describe their experiences from the time they entered the WTC towers until they finally exited the towers, and
- a *Semi-structured Interview* during which the interviewer clarified details and elicited more precise information regarding the participant's entire evacuation experience.

Throughout, interviewers attempted to extract information from the participant in relation to the time and location of their described experiences relative to global time markers, e.g. impact on WTC1, impact on WTC2, collapse of WTC2. Their perception of risk (on a seven point Likert scale) at key points throughout their evacuation was also determined, i.e. at WTC1 impact (or recognition that something unusual was happening), when the participant was deciding to evacuate, when the participant knew that WTC2 had been hit (if applicable), and when the participant knew WTC 2 had collapsed (if applicable).

The HEED database currently comprises the pre-interview questionnaires, full interview transcripts and coded data of 271 persons who evacuated WTC1 and WTC2 on 9/11. The database is structured to include behaviours and experiences during seven distinct phases namely pre-recognition, recognition, response, horizontal evacuation, vertical evacuation, evacuation interruption and exiting the WTC complex.

This paper focuses on an analysis of the recognition and response phases of occupants of WTC 1 where *recognition and response* phases together are defined as "*the time from when an occupant receives the first cue until they start to move towards an exit*".

### THE SAMPLE

The data presented in this paper relates to a sample of 126 persons who evacuated WTC 1 on 9/11. The participants comprised 62.7% (n=79) male and 37.3% (n=47) female, with ages ranging from 24 to 68 (mean age of 46.3). Among the participants only 8.7% (n=11) recorded having a fire safety role within their respective organisations. These roles included: Floor Warden (4%, n=5), Deputy Floor Warden (3.2%, n=4), and Searcher (1.6%, n=2.). Of those participants who had a designated fire safety role, 81.8% (n=9) reported having received specific training from their employers. From the pre-interview questionnaire, 42.8 % (n=54) of participants indicated that they had a managerial/supervisory role. It was also established that 19% (n=24) of participants had evacuated the WTC during the 1993 bombing.

### PROCEDURES FOR ANALYSIS

The analysis presented in this paper required consideration of Pre-Interview Questionnaire data, coded experience data, including risk perception measures, participant's Behavioural Patterns (BPs) and, in some cases, direct information from the transcripts, all of the which is contained within the HEED database. A total of 69 different activities undertaken by participants during the response phase were identified which, for practical purposes, were combined and reduced to 17 generic activities by considering naturally occurring themes. The response activity definitions developed are given in Table 1. The cues received were similarly categorised, Table 2.

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**Table 1 – Response Activity Definitions**

Act of Normal Routine Prior To Evacuation	Participant conducted act(s) of normal routine that include locked office door, switched off electrical appliances, used toilets, locked away item.
Active protective action (self and others)	Activities such as: took cover (hid behind, under or inside something in order to remove his/herself from harm's way), distributed emergency item combated fire, blocked or sealed smoke cracks.
Collected Belongings	Participant collected an item that was originally used for personal or work purposes, e.g., handbag, cell phone, laptop, discs and clothing.
Continued to Work	Participant sustained normal working behaviours, e.g. finished work, text message, phone call, trading.
Gathered and/or made emergency equipment	Participant gathered and or made item(s) that may be deemed necessary in the evacuation eg fire extinguisher, flashlight, whistle, emergency hammer, water, cloth to act as a mask for a smoke barrier etc.
Grouped Together	Participant assembled with other(s).
Physically Removed People From Situation	Participant physically removed other(s) from either a situation or an activity deemed dangerous by the participant e.g. physically removing others who insisted in continuing to work.
Provided assistance verbally	Participant assisted others by e.g. verbally providing direction to evacuate
Provided Information To Emergency Services	Participant used a telephone in an attempt to provide the emergency services with information which may include whereabouts of the participant and the events occurring in the building.
Provided Information To External Source	Participant used a telephone to provide external sources (e.g. family and friends) with information.
Provided Safety Instructions	Participant instructed other(s) to hide behind, under or inside something in order to remove themselves from harm's way
Provided Verbal Comment To Evacuate	Participant suggested to or instructed others to vacate the building
Searched (Physically and Verbally)	Participant either actively searched or verbally called out in search for other/s. Searches included open plan and/or enclosed areas e.g. offices bathrooms.
Sought Information on Event	Participant gathered information from other(s), dialogue or observation, e.g. physically moving to seek information or making phone call to security.
Waited For Further Information / Instruction	Participant waited, e.g. on announcement of safety procedures, rescue and finding out more information.

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**Table 2 - Cue Definitions in the Recognition Phase**

Heard Impact	Environmental sounds as heard by the participant inside and outside the WTC, e.g., explosion and crunching sound.
Felt impact	Physical sensation, e.g., felt building shake and physically moved by impact, experienced by participant.
Saw or heard Incoming Plane	Saw or heard an aeroplane that was heading towards their tower, e.g., saw incoming plane, plane becoming higher pitched, heard roaring sound.
Saw Smoke / Fire Internally	Saw smoke or fire inside the tower.
Saw Smoke / Fire Externally	Saw smoke or fire outside the tower, e.g., saw burning debris outside WTC, saw burning liquid falling.
Experienced Internal Phenomena	Heard, saw, smelt and/or felt unusual environmental conditions inside the tower, e.g., heard screaming, metal in tower groaning and lights flickering.
Saw External Debris	Saw changing environmental conditions outside the tower, e.g., saw plane debris and saw debris falling.

### RESULTS OBTAINED

For the purposes of this paper, and further analysis, participants were divided into three floor clusters (identical to those used in the NIST study<sup>11</sup>). These clusters comprised floors 1 to 42, 43 to 76 and 77 to 110, which were the locations of 45 (36.4%), 57 (46.0%) and 24 (17.7%) participants respectively. The participants were fairly evenly distributed in terms of their locations on the floors with the majority of participants in each floor cluster indicating that they were located at, or around, their work stations at the time of impact (n=78, 61.9%). The remainder were in various other locations including others work stations/office, lobby, elevator etc. The most frequent pre-event activity was ‘working on computers’ (n= 43, 34.1%) followed by ‘talking’ (n=36, 28.6%).

#### Initial Cues at Impact

Table 3 presents a breakdown of the participants’ initial cues at impact by floor cluster.

**Table 3 - Initial Cues Indicating Something was Wrong**

Initial Cues	Floor Cluster			
	Lower (1-42) %	Central (43-76) %	Upper (77-110) %	All Floors %
	(n=45)	(n=57)	(n=24)	(n=126)
Felt impact	97.8	98.2	91.7	96.8
Heard Impact	64.4	57.9	83.3	65.1
Experienced Internal Phenomena	44.4	42.1	54.2	45.2
Saw External Debris	15.6	17.5	12.5	15.9
Saw or heard Incoming Plane	8.9	12.3	12.5	11.1
Saw Smoke / Fire Internally	0	7.0	29.2	8.7
Saw Smoke / Fire Externally	4.4	1.8	0	2.4

Note - Calculations for Table 3 are related to percentage of participants on each floor cluster.

From Table 3 it is evident that 11% of the sample actually saw and/or heard the plane that impacted WTC1. The majority of these (71.4%, n=10) were located on the impact side of WTC1, while the remainder were located in the Eastern (14.3%, n=2), South Eastern (7.1%, n=1) and the central

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locations (7.1%, n=1) on their respective floors. Approximately 97% of participants across all floor clusters indicated that they felt the impact. In addition, approximately 65% of all participants indicated that they heard an impact sound and, perhaps not surprisingly, this was experienced by a greater percentage of participants (83.3%) in the upper floor cluster compared to those in the lower and central clusters. The proportion of participants in the upper floor cluster who 'heard impact' was significantly higher than the proportion of participants in the central floor cluster ( $p=0.02$ ) with trend differences evident between the upper and lower floor clusters ( $p=0.08$ ). From Table 3, it is also evident that participants from the upper floor cluster were more likely to experience 'internal phenomena' than those participants in the lower and central floor clusters. It was also found that significantly more participants in the upper floor cluster experienced 'seeing fire and smoke internally' compared to those on the central and lower clusters (Fishers,  $p=0.01$ ).

### Recognition and Response Time

As noted previously recognition and response refers to "*the time from when an occupant receives the first cue until they start to move towards an exit*". In the HEED study participants' response time was determined in relation to key time points. Analysis of the data indicates that the majority of participants (84.4%, n=107) initiated evacuation within 8 minutes of the WTC1 impact. The remaining 15.6% (n=19) took more than 8 minutes to begin their evacuation with just over half of this group evacuating 'between 08:55 and 09:03 or 8 to 16 minutes after the first impact (7.9%, n=10). Four % (n=5) of participants did not respond until after WTC2 was hit, i.e. more than 16 minutes after the initial impact on WTC1. Three of these late responders were located in the upper floor clusters, with the remaining two participants were located in the central and lower floor clusters.

### Initial Response Activities

The initial response activities of participants are given in Table 4. Table 4 indicates that the most frequently occurring initial response across all floor clusters was to 'seek information on event' (24.6%). The second most frequent initial response was to 'collect belongings' (17.5%) followed closely by 'provided verbal instruction to evacuate' (15.1%). It is also interesting to note that 11% of participants 'initiated evacuation' as a first response.

From Table 4 it is apparent that there are some differences in the initial response of participants across the floor clusters. For example, participants on the upper floor cluster were more likely to take 'active protective action' as a first response compared to other clusters. They were also more likely to 'provide information to external sources' and 'provide information to emergency services'. It is also interesting to note that no-one on the upper cluster reported 'waiting for further information/instruction' or indeed 'continuing to work' as a first action. Participants on the central floor cluster were significantly more likely to 'collect belongings' than those in the lower cluster (Fishers,  $p = 0.03$ ); the reason for the greater prevalence of activity 'collected belongings in the central cluster is not clear. It is also apparent that participants located in the lower floor cluster were more likely to 'wait for further information/instruction' than those on the upper (Fishers = 0.03) and central floor clusters (Fishers,  $p = 0.04$ ). It is also apparent that 'seeking information' was slightly more prevalent on the lower cluster, although the differences between the lower and other clusters were not significant.

### 'Global' Activities

Table 5 details participants' 'global' activities during the response phase, i.e. the numbers and percentages of participants who undertook a particular activity *at any time* during the response phase. From Table 5 it is evident that the most prevalent activity across the whole sample was 'collected belongings' with just over half of all participants reporting collecting belongings at some stage during the response phase. The next two most prevalent activities across the whole sample were: 'provided verbal instruction to evacuate' (31.7%) and 'sought information on the event' (31.0%).

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**Table 4 - Initial Response Activities to the Impact on WTC1**

Initial Activities	Floor Cluster			All Floors (n=126)
	Lower (1-42)	Central (43-76)	Upper (77-110)	
	%	%	%	
	(n=45)	(n=57)	(n=24)	
Sought Information On Event	28.9	21.1	25.0	24.6
Collected Belongings	8.9	24.6	16.7	17.5
Provided Verbal Instruction To Evacuate	15.6	19.3	4.2	15.1
Initiated Evacuation	13.3	8.8	12.5	11.1
Waited For Further Information / Instruction	17.8	5.3	0	8.7
Active Protective Action (self and others)	4.4	5.3	16.7	7.1
Grouped Together	4.4	5.3	4.2	4.8
Gathered Or Made Emergency Equipment	2.2	1.8	4.2	2.4
Continued to Work	2.2	3.5	0	2.4
Provided Information to External Source	0	1.8	8.3	2.4
Provided Assistance – Verbal	0	1.8	4.2	1.6
Act of normal routine prior to Evacuation	2.2	0	0	0.8
Provided Safety Instructions	2.2	0	0	0.8
Searched (Physical And Verbal)	0	1.8	0	0.8
Provided Information To Emergency Services	0	0	4.2	0.8

**Table 5 - Global Activities Conducted in Relation to Floor Clusters**

Global Activities	Floor Cluster			All Floors (n=126)
	Lower (1-42)	Central (43-76)	Upper (77-110)	
	%	%	%	
	(n=45)	(n=57)	(n=24)	
Collected Belongings	46.7	59.6	37.5	50.8
Provided Verbal Instruction to Evacuate	33.3	31.6	29.2	31.7
Sought Information on Event	33.3	28.1	33.3	31.0
Waited For Further Information / Instruction	17.8	15.8	8.3	15.1
Grouped Together	6.7	14.0	29.2	14.3
Gathered Or Made Emergency Equipment	13.3	10.5	16.7	12.7
Active Protective Action (Self and others)	8.9	8.8	29.2	12.7
Searched Verbal / Physical	8.9	14	4.2	10.3
Provided Assistance Verbal	6.7	8.8	16.7	9.5
Provided Information to External Sources	4.4	7	20.8	8.7
Act of Normal Routine Prior To Evacuation	4.4	10.5	0	6.3
Provided Safety Instructions	2.2	5.3	4.2	4
Continued to Work	4.4	3.5	0	3.2
Provided Assistance Physical	0	5.3	4.2	3.2
Provided Information to Internal Sources	4.4	0	4.2	2.4
Provided Information to Emergency Services	0	0	12.5	2.4
Physical Removed People From Situation	4.4	0	0	1.6

Note - Totals do not add up to 100% as participants completed multiple activities.

Table 5 also indicates differences in the prevalence of particular activities across the floor clusters. For example, although ‘collected belongings’ was the most prevalent activity across the sample, it was

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more prevalent in the central cluster (59.6%). Table 5 indicates a number of activities that were more prevalent on the upper floor cluster namely 'grouped together', 'gathered or made emergency equipment', took 'active protective action', 'provided information to external sources' and 'provided information to emergency services'. These actions are perhaps not surprising given the more extreme conditions experienced on the upper floors. Significance testing indicated that the proportion of participants in each floor cluster differed significantly in relation to taking 'active protective action' ( $\chi^2 (2) = 7.25, p=0.03, 2$  tailed) and 'grouping together' ( $\chi^2 (2) = 6.48, p=0.04, 2$  tailed). It is also interesting that none of the participants from the upper floor cluster reported having completed an 'act of normal routine prior to evacuation' or 'continued to work' at any stage during the response phase in comparison to a small proportion of participants located in the central and lower floor clusters.

### Perception of Risk

During the interview, participants were invited to rate their perceived risk on a 7 point Likert scale at two time points, i.e., when they first became aware that something unusual had occurred ('impact') and when they initiated evacuation ('evacuation'). Table 6 presents comparisons of risk perception across the floor clusters. From Table 6 it can be seen that participants located in the upper floor cluster rated their risk on average greater at both 'impact' and 'evacuation' than participants located in the central and lower floor clusters. Kruskal Wallis Test indicated that the participants' floor cluster was a significant factor in perception of risk at initial impact ( $\chi^2 (2) = 9.28, p=0.01$ ) but not when making the decision to evacuate ( $\chi^2 (2) = 3.65, p=0.16$ ). Pairwise comparisons indicated that participants located in the upper floor cluster scored significantly higher on the perception of risk scale at initial impact than the participants in the lower floor cluster (Mann-Whitney U=211.50, p=0.01, one-tailed) and central floor cluster (Mann-Whitney U=182.00, p=0.02, one-tailed). Table 6 also shows that participants on the central and lower floor clusters displayed slight increases in risk perception between 'impact' and 'evacuation'. In contrast, the mean perception of risk scores for the upper floor participants decreased slightly between 'impact' and 'evacuation' administrations.

**Table 6 - Perception of Risk Scores across Floor Clusters**

<i>Floor Cluster</i>	<i>Perception of Risk</i>	<i>No. of Participants</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Median</i>	<i>Mean</i>	<i>Standard Deviation</i>
Lower (1-42)	Impact	39	1	7	4	4.38	1.97
	Evacuation	38	1	7	5	4.74	1.80
Central (43-76)	Impact	42	1	7	4	3.86	1.91
	Evacuation	43	1	7	4	4.28	1.67
Upper (77-110)	Impact	17	3	7	7	5.53	1.70
	Evacuation	17	2	7	5	5.24	1.92

### Relationship between Risk Perception and Initial/'Global' Activities

The relationship between risk perception and both initial and global activities was explored. It was found that participants who reported 'continuing to work' as an initial activity were found to have significantly lower perception of risk than participants who did not continue to work (U=52.50, p=0.03, one-tailed). Furthermore, analyses indicated that those who did not 'collect belongings' had significantly higher perception of risk than those who did (U=417.00, p=0.02, one-tailed). Also those who 'grouped together' and 'provided information to emergency services' had significantly higher perception of risk than those who did not (U=972.50, p=0.05, one-tailed; U=46.50, p=0.02, one-tailed).

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### Responsibility for supervising or managing other people/fire safety role

Table 7 provides a breakdown of the activities performed by participants with and without managerial/supervisory and fire safety roles. Analysis of the frequencies of those with and without managerial roles indicates that they were fairly evenly distributed within each floor cluster.

**Table 7 Global Activities by Managerial and Fire Safety Role**

Activity	Managerial		Fire Safety Role	
	Yes (%) (n=54)	No (%) (n=72)	Yes (%) (n=11)	No (%) (n=115)
Collected Belongings	46.3	54.2	63.6	49.6
Sought Information on Event	27.8	33.3	9.1	33.0
Provided Verbal Instruction to Evacuate	48.1	19.4	27.3	31.9
Waited For Further Information /Instruction	11.1	18.1	9.1	15.7
Grouped Together	20.4	9.7	18.2	13.9
Gathered Or Made Emergency Equipment	14.8	11.1	27.3	11.3
Active Protective Action (Self and others)	13.0	12.5	9.1	13.0
Searched Verbal / Physical	14.8	6.9	18.2	9.6
Provided Assistance Verbal	14.8	5.6	18.2	8.7
Provided Information to External Sources	7.4	9.7	0.0	9.6
Act of Normal Routine Prior To Evacuation	5.6	6.9	0.0	7.0
Provided Safety Instructions	5.6	2.8	0.0	4.3
Continued to Work	1.9	4.2	0.0	3.5
Provided Assistance Physical	5.6	1.4	0.0	3.5
Provided Information to Internal Sources	1.9	2.8	0.0	2.6
Provided Information to Emergency Services	3.7	1.4	0.0	2.7
Physical Removed People From Situation	3.7	0.0	9.1	0.9

Table 7 indicates that those with managerial roles were more likely to 'provide verbal instruction to evacuate', 'group together', 'provide assistance verbally' and 'search verbally and physically'. These differences are perhaps not surprising, i.e., one would expect a manager/supervisor to take responsibility for others during an emergency situation. The difference in 'provide verbal instruction to evacuate' was found to be significant (Fishers =  $p=0.001$ , 1 tailed). Further analysis considered whether this difference was related to floor cluster. Analysis indicated that within the lower and central floor clusters there were significant differences in the prevalence of this activity for those with and without a managerial role (Fishers,  $p = 0.04$  and Fishers,  $p = 0.02$  for lower and central clusters respectively). With respect to the upper cluster, visual differences in the prevalence of 'provided verbal instruction to evacuate' was evident between those with and without a managerial role (41.5% (n=5) and 16.7% (n=2) respectively), however small numbers prevented any further statistical analysis in this respect.

Table 7 also gives a breakdown of activity by whether or not participants had a fire safety role. It should be noted that none of the participants on the upper floor cluster had a fire safety role. Also, since the numbers with a fire safety role are generally small, any further analysis by floor cluster was not deemed appropriate. Notwithstanding, the results tentatively suggest that those with a fire safety role were less likely to 'seek information on the event' (9.1% compared to 33%) and more likely to 'gather or make emergency equipment' (27.3% compared to 11.3%) and 'search verbally/physically' (18.2% compared to 9.6%) than those without a fire safety role.



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### 1993 WTC1 bombing

As noted earlier 19% (n=24) of the sample reported having evacuated the WTC previously in 1993. Analysis indicated that the most frequent activities of those who had evacuated in 1993 were 'collected belongings' and 'provided instruction to evacuate' (each 41.7 %, n=10). Other frequent activities of those who had evacuated in 1993 were 'provided verbal assistance' (29.2%, n=7) and 'searched verbally/physically' (25.0%, n=6). On the other hand, the most frequent activities of those who did not evacuate in 1993 were 'collected belongings' (53.7%, n=44) and 'sought information on the event' (34.1% n=28). Interestingly, 'sought information on event' was significantly less prevalent (Fishers = 0.03) among those who had evacuated in 1993 compared to those who had, while 'provided assistance verbally' and 'searched verbally/physically' were significantly more prevalent (Fishers p = 0.01 and Fishers p=0.02 respectively). Further analysis by floor cluster was not conducted and would be required before any firm conclusions related to prior experience might be drawn.

### CONCLUSIONS

Information relating to the experiences and activities of WTC1 and 2 evacuees are contained in the relational High-rise Evacuation Evaluation Database (HEED). HEED has been used to investigate the experiences and activities of WTC1 evacuees, during the recognition and response phase following the impact on WTC1.

The results indicate that the most prevalent cues received by participants on all floor clusters were 'felt' and 'heard' the impact. It was found that significantly more participants in the upper floor cluster experienced seeing fire/smoke internally and hearing the impact in comparison to those located in the central floor cluster.

The magnitude, volume and intensity of the cues was evident by the finding that more than 11% of the sample initiated evacuation as an initial response, and over 45% of participants immediately initiated activities which could be considered to be in preparation for evacuation. However, a large percentage did not initiate evacuation, with the most frequently occurring initial response in all floor clusters being to 'seek information on event'.

Overall, approximately 85% of participants initiated evacuation within 8 minutes of WTC1 impact on WTC1. Most participants did not waste time on delaying activities, e.g. wait on information/instruction. Where significant delays in evacuation were reported, these were mainly due to prevailing environmental conditions, following the instructions of others and waiting on help.

Both significant and trend differences between participant activities across the floor clusters have been highlighted. It was found that significantly greater proportions of participants in the upper floor cluster conducted 'active protective action' compared to the lower and central floor clusters. It was also found that significantly greater proportions of participants in the upper floor clusters 'grouped together' compared to those located in the lower floor cluster with trend differences observed between the upper and central floor clusters. The results also indicate that significantly greater proportions of participants in the upper floor cluster 'provided information to external sources' compared to the central floor cluster; trend differences were observed between the upper and lower floor clusters in this respect. A trend difference was also evident with respect to 'collected belongings' i.e. a greater proportion of participants in the central floor cluster 'collected belongings' compared to the upper floor cluster.

Differences in the perception of risk between the floor clusters were also identified, i.e. participants located in the upper floor cluster had a higher perception of risk at both initial impact and initiation of evacuation than those on the central and lower clusters; the perception of risk of upper floor cluster occupants was significantly higher at impact than the perception of risk of central floor cluster occupants. Risk perception also increased significantly over time, i.e. during the recognition and

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response phase, for both the central and lower floor clusters. However, this was not evident for participants on the upper cluster, perhaps due to their already elevated perception of risk.

Differences in the responses of participants across the floor clusters have been identified and it is suggested that these can be explained at least in part by differences in the intensity/frequency of cues received and the differences in risk perception across the clusters. Analyses of activities conducted by the participants related to their risk produced some interesting findings. For example, and perhaps not surprisingly, participants who 'continued to work' as an initial activity were found to have significantly lower risk perception scores than those who did not 'continue to work'. Also participants who 'grouped together' and 'provided information to emergency services' had significantly higher perception of risk at initiation of evacuation than those who did not. Results also indicate significantly higher perception of risk among those who did not 'collect belongings' compared to those who did.

Analysis of the activities of participants with and without managerial roles suggests that those with managerial roles were more likely to 'provide verbal instruction to evacuate', 'provide assistance verbally/physically' and 'search verbally/physically'. The differences between those with and without managerial roles who 'provided verbal instruction to evacuate' was significant for those on the lower and central floor clusters. The differences in the propensity of those with and without managerial roles to engage in various activities is perhaps not surprising, i.e., one would expect a manager/supervisor to take responsibility for others during an emergency situation. Although the numbers in the sample who had a fire safety role was small, there is a suggestion that they were more pro-active in terms of responding to the developing situation, e.g., by 'gathering or making emergency equipment', 'searching verbally/physically'.

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### REFERENCES

- <sup>1</sup> Proulx, G., Sime, J.D., To Prevent Panic in an Underground Emergency: Why not Tell People the Truth? Proceedings of the Third International Symposium on Fire Safety Science, Elsevier Applied Science, New York, 1991, pp 843-852.
- <sup>2</sup> Sime, J.D., Escape Behaviour in Fires Design Against Fire: An Introduction to Fire Safety Engineering Design, London, Chapman Hall, 1994.
- <sup>3</sup> Bryan, J.L., Behavioural Response to Fire and Smoke, SFPE Handbook of Fire Protection Engineering Second Edition, National Fire Protection Association, 1995, pp 3-242 - 3-262.
- <sup>4</sup> Canter, D., Studies of Human Behaviours in Fire: Empirical Results and Their Implications for Education and Design, Building Research Establishment Report, 1985.
- <sup>5</sup> Shields T.J, Boyce K.E., A Study of Evacuation from Large Retail Stores, Fire Safety Journal 2000; 35: 25-49.
- <sup>6</sup> Proulx, G., Fahy, R., The Time Delay to Start Evacuation: Review of Five Case Studies, Proceedings of the Fifth International Symposium on Fire Safety Science, Melbourne, Australia, International Association of Fire Safety Science, 1997; 783-794.
- <sup>7</sup> Saunders, W.L., Occupant Decision Making in Office Building Fire Emergencies, Proceedings of the Fifth International Symposium on Fire Safety Science, Melbourne, 1997; 771-782.
- <sup>8</sup> Purser, D.A., Bensilum M., Quantification of behaviour for engineering design standards and escape time calculations, Safety Science, 2001; 38: 157-182.
- <sup>9</sup> Gershon, R.R.M., Hogan P.H.G., Qureshi, K.A. and Doll, L., Preliminary Results from the World Trade Center Evacuation Study, MMWR, Sept 10, 53 (35), pp 815-817, 2004.
- <sup>10</sup> Galea, E.R., Blake, S.J., Collection and Analysis of Data relating to the evacuation of the World

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- Trade Centre Buildings on 11 September 2001, Report produced for the UK ODPM, Fire Research Technical Report 6/2005, ODPM Publications, ISBN 1851127658, Dec 2004.
- <sup>11</sup> Averill, J.D., Mileti, D. S., Peacock, R.D., Kuligowski, E. D., Groner, N., Proulx, G., Reneke, A. P., and Nelson, H.E., Final Report on the Collapse of the World Trade Center Towers, NIST NCSTAR 1-7, Federal Building and Fire Safety Investigation of the World Trade Center Disaster, Occupant Behaviour, Egress and Emergency Communications, September 2005.
- <sup>12</sup> Galea E.R., Shields T.J., Canter D, Boyce K.E., Day, R., Hulse, L., Siddiqui, A., Summerfield, L., Marselle, M., Greenall, P., The UK WTC 9/11 Evacuation Study: Methodologies used In the Elicitation and Storage of Human factors Data.", Proceedings of the 11th International Fire Science & Engineering Conference, Interflam 2007, 3-5th September 2007, Royal Holloway College, University of London, UK, Volume 1, pp. 169-181. ISBN 978 0 9541216-8-6, 2007.
- <sup>13</sup> Galea, E.R., Shields, J., Canter, D., Boyce, K. Day R, Hulse L, Siddiqui A, Summerfield L, Marselle M, Greenall P, Methodologies employed in the collection, retrieval and storage of human factors information derived from first hand accounts of survivors of the WTC disaster of 11 September 2001, Journal of Applied Fire Science, Vol 15(4), pp 253-276, 2008.