STUDIES ON HUMAN BEHAVIOUR IN FIRES IN CHINA

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ABSTRACT

With the rapid development of economy in China, many big city groups were established. Consequent to having so many big fires in the world and implementing performance-based design for new buildings having difficulties to comply with the prescriptive fire codes, evacuation in a fire has to be studied carefully in many big projects.

Human behaviour in fires becomes a hot research topic in China. Psychological aspects of human behaviour in fires have been studied extensively in western developed countries for almost a century. It is worthwhile to understand the development in those countries. Reviewing the literature on human behaviour in fires in the western developed countries becomes the objective of this paper. Further, development of some studies in China is outlined. Topics requiring further studies are also discussed.

1. INTRODUCTION

Economics in China has been growing rapidly in the past 10 years. At least three city groups with dense urban areas in the capital zone, Yangtze River Delta and Pearl River Delta were established. Many new buildings with new architectural features were constructed. Those buildings used to have difficulties in complying with the current fire safety codes. On the other hand, many big fires happened all over the world including China and Hong Kong. Examples were the fires in Dongdu, Luoyang; in a Web Cafe and Jingmin Building in Beijing; Tiantan Hotel in Harbin, Heilongjiang; Zhongbai Commercial Building in Jilin, Jilin; Qiaonan Market in Changde, Hunan; Jiaxing in Zhejiang; Huanan Hotel in Shantou, Guangdong and the big Garley Building fire in Hong Kong [1]. All these fires had led to serious consequences with big life and property losses, raising public concern on safety.

At least three main aspects were identified in causing such big fires:

- Architectural features such as complicated structures, new decorative materials passing some old standard tests but not necessarily safe, and improper fire safety provisions.
- Rapid fire development leading to smoke spreading, high toxicity level, and damaging the structures.
- Human psychological and behavioural factors such as inadequate staff training and the lack of a proper fire action plan in fire safety management [2].

Efforts were made on studying building fire environment in China. However, very few works on human behaviour in fires were reported. Fire safety provisions related to evacuation have to be designed with a good understanding of human behaviour in fires. In contrast to building fires, data on human behaviour from overseas studies might not be applicable to local situations. But it is still important to understand overseas works on human behaviour in fires so that the results can be modified. At least, similar studies might be repeated to get suitable design data in China.

In this paper, research and major findings on human behaviour during fire in overseas developed countries are reviewed. Roughly speaking, three periods can be identified on exploring the topics before 1970; rapid development period from 1970 to 1990; and performance-based design afterward. Current development on studying human behaviour in fires in China is outlined. Hot topics requiring urgent investigation are discussed.

2. EXPLORING PERIOD

The first period was on exploring the key topics before 1970. Human behaviour during evacuation was studied systematically in the USA. Design of the Hudson Terminal in New York in 1909 was based on the measured walking speeds of passengers. Through ten years of evacuation studies from 1917, the first edition of Building Exits Code was issued by NFPA in train stations, subway stations, theatres, shopping malls and federal government office buildings were studied. The flow of people at normal exits and emergency exits were focused on with results published in 1935 [3].

Studies on human behaviour in building fires in the USA started from the 1950s. In 1956, "re-entry" behaviour to the fire scene of the family members in the investigation of the Arundel Park fire incident was confirmed [3]. Panic behaviour of people in fires was also studied. Although the studies were focused on the building fire control and extinguishment, the importance of human behaviour was recognized. Such studies in the USA included the works from the National Bureau of Standards, Fire Protection Associations in most of the states and the fire research teams at University of California and University of Maryland.

Long-term studies and observations on people evacuation at staircases were started by Pauls [4] in 1968. The developed "drill" method became one of the key methods for studying evacuation behaviour.

3. RAPID DEVELOPMENT PERIOD

Basically, studies on human behaviour in fires developed rapidly from 1970 to 1990. Two important areas were started and completed by Wood and Bryan respectively. Victims in fire incidents in the USA and UK were interviewed by Wood for cross-cultural comparisons. Structured questionnaires commonly employed at the University of Maryland were used. Fire victims in the USA in several big fire incidents were interviewed by Byran to study the reaction mode of behaviour during a fire. The "clustering" phenomenon was identified in 1979 by Bryan in studying the Georgia apartment fire. It was pointed out that apart from the physical difference in smoke and heat between a fire drill and a real fire evacuation, there are also differences in psychological and physiological experiences [3].

In the early 1970s, a new theory was proposed by Lars Lerup and coworkers [5] at University of California. The fire development stage was found to be in line with the stages of human behaviour. Based on this theory, a "Graphical handbook" on the method for dynamic analysis of human behaviour in fires was published in 1977. Survey and interview methods were integrated by this dynamical approach. The technique was then adopted widely worldwide for studying human behaviour in fires.

Within this period, aspects of psychology on human behaviour in fires were studied together with psychologists [6-8]. Spatial cognitive memory, fire signals cognition, alarm systems, information flow under emergency conditions, emergency evaluation in a fire, reasoning of the escape behaviour, psychology in a fire and post-fire mental help were studied. Two symposia were organized in 1974 and 1978 respectively. A book collecting a large volume of research findings was edited by Canter [9] in 1980.

Computer simulations on the evacuation of people started in the late 1970s. The BFIRES model was reported by Stahl [10] from the Environmental Design Research Division, Center for Building Technology, National Bureau of Standards in 1979. It was applied to study human evacuation behaviour in building fires by simulating emergency evacuation and rescue scenarios in multi-story building fires. Evacuation simulation is still a focused subject area.

Apart from the USA, similar researches were also conducted in the UK and Japan during this period. Universities, research institutions and consultancy companies were included. Some works were reported [11] in New Zealand, Sweden, Norway and Australia.

4. PERFORMANCE-BASED DESIGN PERIOD

Buildings with new architectural design features appeared all over the world. Such buildings might have difficulties in complying with the fire codes, giving many safety concerns. Performance-based designs have become a global trend since 1990. Most of the quantitative studies were related to the buildings and their environment. There were relatively few studies on human psychology and behaviour. Some fire research activities were stimulated after the first explosion incident of the World Trade Center in 1993. More studies were started after the twin towers collapsed on 11 September, 2001 [12].

Three international symposia [13-15] related to human behaviour in fires were held in 1998, 2001 and 2004. Useful findings all over the world were reported.

The main topics [13] of the first symposium included the fire-related human behaviour; fire regulations and codes; knowledge of human behaviour in fires; reception, evaluation and application of information in fires; characteristics of building usage and complicated environment; evacuation of people with physical disability; risk assessment of fire exposure; evacuation time and measurement of evacuation capability; characteristics of people in the building and decision-making mechanism of human behaviour; ability to find ways in complicated environment, behaviour of walking through smoke; evacuation models and confirmation methods.

Topics [14] discussed in the second symposium were on theories of human behaviour; evacuation models and their functions; spatial characteristics of people inside the building; reactions of people in a fire; effects of toxicity and smoke; non-engineering solutions to reducing fire incidents and the associated effects; visibility and space analysis; standard on evacuation capability of people in fire regulations and codes.

The main themes of the third symposium [15] were on community fire safety behaviour; reliability of fire protection systems; studies on the vulnerable groups of people; and the influences of the major fire phenomena on human behaviour.

There were also similar symposia [e.g. 16]. Factors affecting human behaviour in fires were summed up by Proulx [17] in 2001. Behaviour is believed to be determined by psychological and physiological factors. Human psychology and physiology are dependent on three external factors: characteristics of people, building and fire environment. Characteristics of people are divided into basic personal situations, knowledge and experience, conditions, personalities and roles. Building characteristics are classified into function, structure, activities inside the building, and fire protection properties. Characteristics of fire environment include visual, smelling, hearing and other hints like heat. As pointed out by Sime [18], more important factors are the building dimensions, the role of people (public or staff) inside the building, locations inside the building, fire knowledge, familiarity with the evacuation routes and smoke development. Many publications appeared in the literature [19-40] during this period as clearly reviewed by Proulx [17].

Evacuation simulations developed rapidly with many commercial software available. One of the reasons is the implementation of performance-based design. The evacuation models developed in the 1980s were mainly on mass flow models. Effects due to human behaviour during evacuation from the buildings were included more after 1990. Behavioural models take into account not only the physical factors such as the direction of crowd movement, flow density, building geometry and fire environment, but also the effect of environment on individuals and other psychological factors such as the interaction between individuals. Adaptation during target exit selection and other complicated behaviour such as people crawling in a smoke environment are also simulated.

There are two characteristics. The first is "human-based" concept which became more popular in evacuation studies. More attention was paid on human psychology and their behaviour in fires. Many behavioural and psychological models appeared in the literature during this period. The second characteristic is more involvement of computer models in many research projects. The reliability and applicability of the models was upgraded.

5. STUDIES IN CHINA

Performance-based design on fire safety was implemented in many projects in China since 1990. Studies on psychology and human behaviour in fires were then started gradually while extending the application of the developed theory on evacuation.

Research institutes and organizations dealing with fire safety in China include the State Key Laboratory of Fire Science at the University of Science and Technology of China, Faculty of Energy and Civil Engineering of Dongbei University, China University of Mining and Technology, Xi'an University of Architecture and Technlology, Wunan University of Science and Technology, Institute of Civil Engineering and Architecture of Wuhan University, Institute of Building Fire Research at the China Academy of Building Research, Tianjin Fire Research Institute of the Ministry of Public Security and Beijing Municipal Institute of Labour Protection.

Early works on human psychology and behaviour in fires can be found from the books "Human behaviour in Fire" by Li [41] and "Psychology in fire environment" by Zhang [42] published in 1989 and 1993 respectively in China. There, research in western countries interpreted in China at that time was summarized. Now, these topics are part of the funded National 973 Project "Fire Dynamics and Fundamentals of Fire Safety" [43].

Upon smooth reunification of Hong Kong to the Mainland as a Special Administrative Region, fire studies in this region can also be grouped as

Chinese results. Evacuation was studied at the City University of Hong Kong. Human psychological reactions during evacuation were studied preliminary at their Department of Building and Construction since 1996. Based on the information from the survivors in fire incidents, crude models for predicting reactions were proposed. However, such works were not demonstrated to be carried out by clinical psychologists. A spatial grid model SGEM was developed by Fang et al. [44-48] from the Faculty of Civil Engineering and Architecture of Wuhan University in collaboration with City University of Hong Kong. It was applied to public places including underground carparks, theatres and large shopping malls.

On the other hand, research, teaching and consultancy in fire engineering have been carried out actively as an Area of Strategic Development for years at The Hong Kong Polytechnic University. It is now labelled as the Areas of Strength: Fire Safety Engineering upon expiry of public supported funding in 2002. This gives a good reason for carrying out so many consultancy projects since then. Over 20 PhD research students in fire science and engineering were graduated. There is a first degree programme in Fire Engineering which has trained over 200 students. A MSc in Fire and Safety Engineering programme is running at the moment, graduating about 40 students per year. Application of evacuation software to performance-based design projects and fire research activities were reported. Different evacuation models were assessed and applied to study buildings for karaokes, shopping malls, airport terminals, railway terminals, public transport interchanges and crowded atria as several PhD research programmes and consultancy projects [49-53]. Such models might be considered not yet applicable to Chinese as the psychological data was compiled in overseas. However, the models can be used for comparing different evacuation designs.

Researches carried out by the State Key Laboratory of Fire Science, University of Science and Technology of China were focused on smoke models and smoke toxicity [54]. In 1997, a numerical model for calculating the evacuation time was proposed by Yuan. The safety evacuation time was taken as the sum of the fire alarm time and the time all people have evacuated out of the building. However, that model had not considered the confirmation time of the fire for a person, so not regarded as a behavioural simulation model [55]. Evacuation and fire development were combined by Chen to develop the Combined Fire Evacuation (CFE) Model. Effect of cross exits on evacuation was studied. The model was applied to fire hazard assessment of terminal buildings and underground plazas [56,57]. An evacuation model based on cellular automation was developed by Yang and coworkers in 2002 [58-61]. In that model, a two-dimensional floor plan is divided into a uniform grid system. Every grid point has a specific value assigned to each person evacuating, which represents the knowledge of that person on the danger of that grid point. This is called a "danger level diagram", representing the knowledge of that person on the ambient environment at a particular time. The danger parameter changes with time. The fire scenario assumed would include the effect of fire on the moving speed and visibility. The social force model was used by Song et al. to simulate certain phenomena in real life evacuation such as the spontaneous formation of walking passages, congestion, pushing and shoving and intermittent human flow [62].

Simulations on human behaviour in evacuation were started at the Dongbei University in 1995. Computer simulations on the escape behaviour of people in a fire and the patterns of mass behaviour were reported by Chen [63]. Development of an expert system for human behaviour in fires was also discussed. In-depth studies on human behaviour and dynamic analysis on the "clustering" phenomenon during evacuation in fires were reported by Zhang and Wen et al. [64-68]. A dynamic model on human behaviour during evacuation was attempted to develop.

Fire and evacuation models were combined by Zhou and Xie [69] at the China University of Mining and Technology. The developed integrated model included the effects of the temperature and toxicity of the combustion products on human. However, human psychological and physiological characteristics are not fully included in the model.

Fire investigations were studied by Zhang [70,71] from the Xi'an University of Architecture and Technology. Many questionnaires and interviewing data were compiled. Artificial nervous network was applied to study human behaviour and reactions in a fire. Results were compared with works reported in the USA, UK and Japan. Behaviour of people with different cultural background in building fires was analyzed. However, data samples were too small in comparing with those works in overseas. The investigations were only limited to some regions in the Shaanxi, Shanxi and Henan provinces.

The Fire Error Foretell Model System (FEFMS) for misbehaviour analysis and prediction in fire evacuation was proposed by Xiao [72-74] from Hunan University of Science and Technology.

Based on the study of behaviour modification, application mode of such model in fire was proposed. The characteristics of evacuation from highrise buildings were included to correct improper behaviour for highrise residential building fires. The functions and intervening measures of the modification mode were analyzed.

An evacuation prediction model for underground shopping areas was developed by Liu et al. from the Institute of Building Fire Research, China Academy of Building Research. This is an optimization model where the buildings are modeled as nodes with connections using some control principles. It is assumed that people evacuate in good order and do not panic [75,76].

The computer model Fegress was developed at the Tianjin Fire Research Institute for evacuation of people during a fire in underground big shopping malls. Although the effect of different combinations of people on the rate of evacuation was included in the model, the reaction time of people was assumed to be very fast. Individual attributes were not defined. The reaction time used in the model was based on experience or estimation only, giving many limitations in using the model [77,78].

The evacuation simulation software buildingEXODUS from the University of Greenwich, UK was evaluated by Beijing Municipal Institute of Labour Protection. Studies were carried out on practical applications. Key examples included the Wang Fu Jing Street in Beijing, Beijing Subway, temple fair and the design of pedestrian flow in the Shunyi Olympic Aquatic Park [79-81].

In addition, projects on qualitative and quantitative studies on human psychology and behaviour in fireswere started at the three Fire Research Institutes of the Ministry of Public Security in Sichuan, Shenyang and Shanghai; other building and fire research centers and regional fire departments [81-89].

6. KEY TOPICS

Human psychology and behaviour in a fire are very complicated. Results would be affected by different personal and external factors. After studying in overseas with three periods, better theories and methodologies on studying human psychology and behaviour in fires were developed. Key topics of concern were identified. This is a multi-discipline subject linking up architecture, sociology, physiology, psychology, behavioural science, ergonomics, statistics and computer engineering. Key areas are mainly the ways for people to confirm the occurrence of a fire, stages of human behaviour in a fire, order and mode of behaviour, behaviour modelling, as well as decision-making mechanism during evacuation.

6.1 Information Flow and Decision-Making in Fires

Information flow in the field of psychology had been studied for many years. The concept was applied to fire in the past ten years. Cognition, memory and processing of fire signals were studied. Models with psychological aspects were developed and applied [90].

Human behaviour in fires is complicated with many efforts paid. Many behavioural and psychology models appeared in this area. Reception and processing of fire signals by a person can be divided into six processes as awareness, confirmation, definition, evaluation, decision-making and re-evaluation. A model was developed by Breaux et al. to simulate the decision-making process of a person in a fire. There are three basic processes: awareness, behaviour and result, which are affected by factors of the environment and society. The social force model proposed by Helbing in 1995 included the effect or interaction between individual motives. The acceleration, distance and the 'attraction' effect of people are described to better reflect the phenomenon of self-organization. A pressure model was developed by Proulx for describing the different pressure levels in the decision-making process for behaviour in a fire. Psychology and behaviour of people evacuating in a fire from the aspect of psychology were reported [37, 91-96].

Relevant research findings in psychology and human behaviour are integrated. For example, in late 1997, a work group was set up in the USA to study models on people. The work group is composed of research workers of information processing by human and also engineers of marine systems. The focus of the research is to study the role that can be played by people model in the 21st century generation of naval vessels (SC-21). This was discussed by Pew and Mavor in 1998 in a national research committee on ACT-R, COGNET, EPIC, MicroSaint, SOAR and several other integrated models on the behaviour of military staff. These models have integrated the merits of the psychological model on human cognition and behavioural information processing mechanism, and thus enhanced the interaction mechanism between individuals [97].

Studies in the above areas require the knowledge of psychology and behaviourism, especially through interviews with the victims in fire incidents. In

China, fire studies are mainly held responsible by the brigade. The investigations were limited to the causes and liabilities for the fire. Very few works were reported on human psychology and behaviour in fires. Efforts in this research area were reported by Lo and associates at the City University of Hong Kong, Fang from Wuhan University, Chen from Dongbei University and Zhang from Xi'an University of Architecture and Technology. Several decision-making models for behaviour were developed. However, it is necessary to compile a database [68] for better prediction.

6.2 Evacuation Simulation

Since the introduction of performance-based design in 1979, computer simulation has become a hot topic as it is one of the key elements in hazard assessment. Evacuation can be better simulated by paying more effort on scenario analysis.

Long-term studies were conducted by Gwynne, Olenick, Carpenter, Watts, Friedman and Kuligowski in developing computer models with useful conclusions drawn. Nature, spatial presentation, definition of people and behaviour of the models, and model methodology were analyzed by Gwynne. Based on the latest development in late 2004, 28 computer models commonly used were reviewed by Kuligowski [103]. These models were classified into three main types as movement models, partial behavioural models and behavioural models [98-103].

Key data used in the models was deduced from evacuation drills and some fire records. However, not much data are available on the psychological and physiological effects. There are uncertainties of human behaviour in real evacuations. In-depth studies are required for more comprehensive predictions of real fire evacuation scenarios.

In the past, the fire environment was simulated first for predicting the time to reach tenable limits. The required evacuation time was then predicted by evacuation models. These two times were then compared to determine safe evacuation. Separating fire simulation from evacuation simulation is criticized to be unrealistic. Smoke spreading and evacuation would take place simultaneously. Behaviour of people walking through smoke should be simulated. More realistic models can then be developed by integrating such fire simulations with evacuation. Virtual reality might give a better presentation in understanding the possible evacuation patterns.

6.3 Application of Psychology Simulation

"Augmented reality" would give three-dimensional virtual information. People might see how real objects are projected into a virtual environment.

The latest equipment IS-900 motion tracker and Sim Eye XL100A helmet were purchased by the Institute of Psychology of the Chinese Academy of Sciences from the USA. These two equipment were applied to study human spatial cognition and "augmented reality". IS-900 and Sim Eye XL100A can trace the movements of any body parts. The objects that can be seen by the eyes can be shown on a computer monitor. Through the transmission of sound waves, the location of a person can be traced. The technique can be used in fundamental researches on spatial cognition and to simulate spatial environment in a laboratory. All these are essential information in studying the psychological aspect [104].

6.4 Remote Virtual Evacuation Drill System Through the Network

Although effort was made on continuously upgrading the evacuation software through evacuation drills, the results were still not very satisfactory. In such drills, only a small number of people volunteered to participate. The scale of the evacuation drill was very limited, affecting the applicability of the data in scenarios with a large crowded space. Fire investigations in three provinces of Shaanxi, Shanxi and Henan were reported by Zhang. Only 274 valid questionnaires were collected in two years. However, these data might not be applicable to other provinces. This shortfall can be complemented by virtual evacuation drills on the computer network. It is a very popular tool in recent years.

People participating in a virtual drill have to register to enter the virtual environment. Their behaviour in the virtual fire environment would be recorded. Provided that there is a computer network, any computer user can participate in a virtual drill. This method is not constrained by region and site of the experiment. Evacuation data from throughout the country can be collected in one platform. The shortcoming of this method is that the number of children and the elderly using computer network is relatively small. Their data on evacuation behaviour cannot be collected.

The virtual reality simulation system was introduced by Zhang in China through the PASGDREVC model. Some achievements in the development of virtual reality were made by Wang and Fang et al. by using 3D modelling and OpenGel. The results had been applied in the design and evaluation of evacuation routes in karaokes [65,105].

Research results in this aspect have been reported in overseas. The software FreeWalk1, FreeWalk2 and FreeWalk3 developed by Nakanishi et al. [40] in Japan can describe the interflow among people, support cross-cultural interflow between America and Japan, and support virtual drills respectively. Among which, FreeWalk3 supports the simulations of city-scale virtual drills, people can participate in an evacuation simulation of a disastrous scenario at home.

As a new technique, the development of virtual drill is not yet perfect. It is a debatable question on how to transform the acquired data for practical application. But in comparing with traditional methods, this method has better repeatability. It requires little investment and can be used to study the effect of varying a single factor.

6.5 Comparisons with Different Culture

Overseas research results might not be applicable to the local environment due to cultural differences. For example, the importance of human lives is different in different culture. As reported, in a supermarket fire in Shenzhen in 2003, the management lied to the customers that it was only a fire drill. Customers were told to continue their shopping. In fact, the management tried to put out the fire by themselves. However, the valuable time for evacuation was missed, resulting in casualties.

Comparisons were reported by Wood [106] in 1970 on fire escape behaviour with different cultures. Survivors of fire incidents in the USA and UK were interviewed. The same set of questionnaires was used to study the behaviour. Results in China with those of the USA, UK and Japan with different cultural background were compared by Zhang [71]. As the scope, volume of samples and method used were different, there are doubts on the results.

There are so many provinces in China and some of them are very different. For example, very big cultural differences were observed across the northeastern region, the northwestern region, the eastern region and the southwestern region. This is similar to situations in Europe in having different dialects and personalities in areas within short distance apart. In addition to comparing different cultures with other countries, regional comparisons within China are necessary. More efforts should be paid to larger-scale field surveying studies with specific comparing items.

6.6 Database

A database should be compiled on human behaviour in fires, though large resources are required. Most databases were developed in the USA, UK and Japan. Abundant data had already been obtained through long-term research programmes. For example, a long-term study and observations on evacuation of people at staircases was conducted by Pauls from the Institute for Research in Construction, National Research Council of Canada, Ottawa since 1968. The data obtained was applied in drafting the performance-based codes in many countries. Because of the big differences in economic development and culture between China and other countries, those data used in overseas might not be applicable.

There are three steps in compiling a database: data collection; classified studies on people, building and fire scenarios, and summing up the results of different combinations under different scenarios; processing of data based on the requirements of performance-based design and putting them into a database. Specific classification can be referred to British Standard BSI DD240 [107] or other similar standards. There have been debates on the studies on people, building and fire scenarios. Procedures on data collection, processing and summing up should be frequently repeated. The database established should be frequently updated to cope with the rapid changes in the society, economics and culture [108]. This was also pointed out by Wen [64] and Xiao [109] in China.

However, there were no further studies on the topic. Fundamental studies in this area are not adequate due to difficulties encountered in developing such database. Without large volume of raw data, it is impossible to compile a database in reflecting the real evacuation scenarios.

7. CONCLUSION

The concept of “human-based” design is now proposed in China. Life safety objective and human behaviour are the focused areas in fire research. Emphasis was put on “hardware fire safety provision” in the past. More emphasis is now put on “software safety management” involving people [110].

Experts in psychology and human behaviour should be involved in the study of decision-making mechanism for behaviour. Cross-cultural comparisons would allow more detailed investigations. More new architectural features and new materials will be found in the near future. Engineering approaches without integrating with psychology are not applicable for evacuation safety. Conclusions drawn in such studies would not provide good guidance on performance-based design [111].

Evacuation behaviour models should be developed. Human behaviour and psychology in fires would become hot research topics. There is an urgent need to study the psychology and behaviour characteristics of people in China under emergency situations. There are few studies on evacuation models in China. At the moment, works were focused on applying models developed and validated in western countries for engineering applications in China. More attention has to be paid to development of evacuation models [71,112] for longer-term research projects.

Researches on human psychology and behaviour in fires require the collaboration among different parties, disciplines and departments. Future studies demand the integration of multiple disciplines, large-scale research collaborations and interflow, well-drafted research plans and exchange of information. Scientific studies on human psychology and behaviour in fires have to be carried out based on the classification of different groups of people. International collaborative research is most welcome.

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