Perceived Severity of Visually Accessible Fires

Karl Fridolf

Perceived Severity of Visually Accessible Fires

Karl Fridolf

Lund 2010

Upplevd allvarlighet av visuellt tillgängliga bränder
Perceived Severity of Visually Accessible Fires

Karl Fridolf

Abstract
Investigations of past fires suggest that building occupants faced with a fire have problems defining the severity of it, especially in the early stages of the fire. An experiment was therefore carried out to study people's ability to estimate fire growth, and their perceived ability to extinguish a fire using a portable fire extinguisher. A total of 535 persons, namely 304 men and 231 women, were asked to fill out a questionnaire that was divided into three parts. In the first part the test participants were asked to estimate the time between different stages of a fire. The second part involved estimations of the own ability to extinguish a fire with a portable fire extinguisher. The third part involved general questions about age, gender and academic background. The results suggest that people in general are not very good at defining the severity of a fire when it is visually accessible. Estimations of the fire growth did not correspond very well to the actual fire growth, and a great proportion of the test participants believed that they had not been able to extinguish an extinguishable fire using a portable fire extinguisher. It is therefore argued that the perceived risk not always conforms to the real risk in a fire situation where the fire is visually accessible. The results can be used to explain why building occupants not immediately initiate evacuation in a fire situation, even when the fire is visually accessible.

Brandteknik och Riskhantering	Department of Fire Safety Engineering
Lunds tekniska högskola	and Systems Safety
Lunds universitet	Lund University
Box 118	P.O. Box 118
221 00 Lund	SE-221 00 Lund
	Sweden
brand@brand.lth.se	
http://www.brand.lth.se	brand@brand.lth.se
	http://www.brand.lth.se/english
Telefon: 046 - 222 73 60	
Telefax: 046 - 222 46 12	Telephone: +46 46 222 73 60
	Fax: +46 46 222 46 12

Summary

In 1981 a fire occurred at a nightclub in Artane, north of Dublin, which claimed the lives of 48 people. Four years later, in 1985, a fire occurred at a football stadium in Bradford city, which killed 56 people. In both fires the flames were clearly visible, however, it took the occupants a couple of minutes before they decided to evacuate. These findings, as well as previous research, suggest that people in general might have problems with defining the severity of a fire in the early stages.

Theories and models in human behaviour suggest that the situation must be defined as a risk before an appropriate decision on what action to take can be made. However, if people have problems with defining the severity of a fire in the early stages, it is likely that a building occupant will arrive at an appropriate decision too late because the risk is underestimated. An experiment was therefore carried out to study how people in general perceive the rate of fire growth when the fire is visible. In addition, people's perceived ability to extinguish fires was studied. A total of 535 persons participated in the experiment, namely 304 men and 231 women. They were students at the Faculty of Engineering at Lund University, employees at Lund University of Economics and Management, employees at IKEA, and senior citizens from PRO and SPF in Malmö and Lund.

A questionnaire including film sequences of fires was created to collect the data. The questionnaire was projected on a screen in front of the test participants, and they were then asked to answer the questions onto a paper version of the questionnaire. The first part of the questionnaire involved subjective estimation of fire growth, and a method was developed where the participants were shown two film sequences of a fire. They were then asked to estimate the time lapsed between the two film sequences. In the second part of the questionnaire the test participants were asked about their perceived ability to extinguish a fire with a portable fire extinguisher. The test participants were shown a looped film sequence of a fire and then asked about their perceived ability to extinguish it with a 6-kilogram powder extinguisher.

The results suggest that people in general have problems predicting fire growth. Even when the estimations of the time between two different film sequences are presented as confidence intervals with a significance level of 95%, the intervals never include the real time difference. In addition, the intervals represent both underestimations and overestimations of the real time, which makes it hard to draw any general conclusions about a person's ability to predict fire growth. For instance, it cannot be assumed that a person systematically underestimates fire growth. The results also suggest that the estimation of fire growth is more or less independent of the growth rate of a fire. In addition, a large proportion of the participants believed that they had not been able to extinguish an extinguishable fire with a portable fire extinguisher.

In terms of predicting fire growth no differences were found between men and women. Neither was a difference identified between different age groups. However, a larger proportion of the men believed that they had been able to extinguish the fires shown in the second part of the questionnaire. This observation suggests that women's perception of risk is somewhat larger than men's.

Altogether the results suggest that subjective estimation of fire growth does not conform to the real fire growth. In addition, the perceived ability to extinguish a fire is misjudged. Hence, it is likely that the perceived risk in a fire situation where the fire is visually accessible does not conform to the real risk, and this may explain why evacuation sometimes have been delayed even though the building occupants have seen the actual flames.

Sammanfattning

1981 inträffade en brand på en nattklubb i de norra delarna av Dublin. I branden omkom 48 människor. Fyra år senare, 1985, inträffade en brand på en fotbollsarena i Bradford City, England, som krävde livet av 56 människor. Gemensamt i båda bränderna var att flammorna var klart synliga för de närvarande gästerna. Trots detta tog det dem flera minuter innan de bestämde sig för att utrymma. Denna upptäckt, som stöds av tidigare forskning, antyder att människor i allmänhet har svårt för att uppskatta allvarligheten av bränder i de tidiga stadierna av ett brandförlopp.

Teorier inom mänskligt beteende vid brand menar att en situation först måste betraktas som en risk innan ett lämpligt beslut kan fattas om vilken åtgärd som ska vidtas. Om det då är så att människor i allmänhet har svårt för att uppskatta allvarligheten av en brand, då är det också troligt att en person kommer att fatta ett beslut om en riskreducerande åtgärd för sent eftersom att risken sannolikt underskattas. Med anledning av detta genomfördes en experimentell studie med syftet att studera hur människor i allmänhet uppfattar brandtillväxt när branden är visuellt tillgänglig. Dessutom undersöktes människors upplevda förmåga att släcka en brand med hjälp av en handbrandsläckare. Totalt deltog 535 personer i studien, nämligen 304 män och 231 kvinnor. Testpersonerna rekryterades som studenter från Lunds tekniska högskola, anställda på IKEA och på Ekonomihögskolan i Lund, samt pensionärer från pensionärsföreningarna PRO i Malmö och SPF i Lund.

Datainsamlingen skedde genom att försökspersonerna fick se en enkät med filmklipp som projicerades på en duk. Samtidigt fick de en pappersversion av enkäten där de ombads lämna sina svar. Den första delen av enkäten handlade om subjektiv uppskattning av brandtillväxt. För detta ändamål utvecklades en metod där testpersonerna fick se två filmsekvenser av samma brand, varpå de ombads uppskatta tiden mellan filmklippen. I enkätens andra del tillfrågades försökspersonerna om sin upplevda förmåga att släcka en brand med hjälp av en 6-kilograms pulversläckare. Försökspersonerna fick här se en upprepad filmsekvens av en brand och därefter svara på om de trodde att de hade kunnat släcka branden med handbrandsläckaren.

Studiens resultat visar att människor i allmänhet har svårt att prediktera brandtillväxt. Även då testpersonernas uppskattning av tiden mellan två filmklipp presenteras som konfidensintervall med konfidensgraden 95% inkluderas aldrig den verkliga tiden mellan klippen i intervallet. Dessutom representerar konfidensintervallen både över- och underskattningar av den verkliga tiden mellan klippen, vilket gör det svårt att dra några generella slutsatser om en persons förmåga att förutsäga ett brandförlopp. Det kan till exempel inte antas att en person systematiskt underskattar bränders tillväxt. Resultatet av enkätens första del antyder också att en persons förmåga att prediktera brandtillväxt är oberoende av brandens tillväxthastighet. En stor andel av försökspersonerna trodde inte heller att de hade kunnat släcka en brand med hjälp av en handbrandsläckare, trots att det hade varit teoretiskt möjligt.

Vad beträffar uppskattningen av brandtillväxt kunde inga statistiskt signifikanta skillnader observeras mellan män och kvinnor. Någon sådan skillnad kunde inte heller observeras mellan äldre och yngre personer. Däremot trodde en större andel av männen än kvinnorna att de hade kunnat släcka de bränder som ingick i enkätens andra del. Detta tyder på att den upplevda risken är något högre hos kvinnor än hos män.

Sammantaget visar resultatet att människors uppskattning av brandtillväxt stämmer dåligt överens med verkligheten. Dessutom missbedömer många människor sin egen förmåga att släcka en brand. Det innebär sannolikt att den upplevda risken från en brand som är visuellt tillgänglig inte alltid överensstämmer med den verkliga risken och det skulle kunna förklara varför människor i vissa fall reagerat sent och avvaktat onödigt länge med att utrymma, trots det faktum att de faktiskt sett flammorna från branden.

Preface

I would like to thank everyone who made the completion of this master's thesis possible.

First of all I would like to thank my supervisor Daniel Nilsson at Lund University for always being available and for all the guidance.

I would also like to thank a number of people who helped me gather test participants for this study, namely: Jörgen Norén at Lund University School of Economics, Petra Flensburg at IKEA Malmö, Ingrid Lundgren, Ulla Larsson and Gertrud Johnson at PRO Husie, Kent Olsson at PRO Borgmästaregården, Gitte Jörgensen at PRO Augustenborg, Claes Bloch at PRO Malmöcentrum, and Jan-Evert Svensson at SPF Lund.

Finally I would like to thank all of the persons who participated in this study. Without you there would be nothing to report.

Karl Fridolf

Table of Contents

1. Introduction

It is commonly believed that building occupants will evacuate when they receive information of a fire. However, experiments as well as past fires demonstrate that this is not the case and that human behaviour in fire is a far more complex process, which among other things involves decision-making under stress. Not even when building occupants have direct visual access to the fire can it be expected that an evacuation will be initiated.

The development of performance-based codes in fire safety design engineering has enhanced the need to understand and predict human behaviour in fire with a high level of accuracy. Thus, there is a need to study the factors that affect the decision-making process. This report concerns one of these factors: perception of fire growth for visually accessible fires, and an experimental study has been performed to examine whether or not people in general are capable of defining the severity of a fire in its early stages.

1.1. Background

Past fires clearly demonstrate that building occupants do not always recognise the need to evacuate in time to reach an area of safety before conditions become untenable. This problem can be illustrated when looking at the Stardust Club fire and the Bradford Football Stadium fire. In both fires building occupants had visual access to the fire, but however, did not initiate evacuation until it was too late.

1.1.1. The Stardust Club Fire

On Saturday, 14th February 1981, a fire started in a nightclub in Artane, a suburb in the north of Dublin, Ireland. The fire began in an upholstered seat and eventually spread to other seats in the immediate area. Of the 846 attending guests, 48 people were killed and 128 people were seriously injured (Keane, 1982; Morris, 1984; Pigott, 1984; Rasbash, Ramachandran, Kandola, Watts, & Law, 2004).

The Stardust Club was a part of a bigger building, originally built in 1948 as a food factory. In 1977-1978 a part of the building that had previously been used for manufacturing chocolate was converted into an amenity centre. Originally the idea was to use the facility for cabarets and concerts, but it was later used for discos as well. A schematic drawing of the facility is shown in Figure 1.1. The fire started in a seat in the back row of the seating area in the west alcove, measuring 17 by 10 metres.
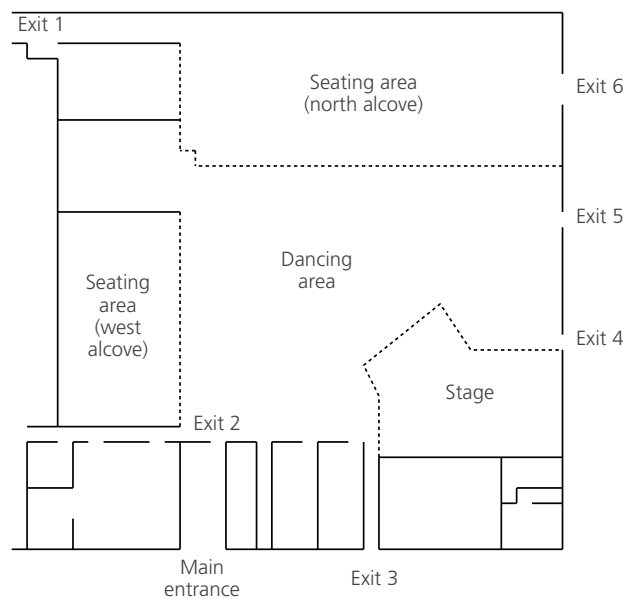

Figure 1.1. The Stardust Club. On the night of the fire the north and the west alcoves were separated from the rest of the room with roller blinds, but parts of the roller blind were raised when the fire was detected. Reproduced from Morris (1984) and Pigott (1984).

On the night of the fire there was a dancing competition in the dancing area, and it was shortly after the competition that the earliest observations of the fire were made. Guests sitting close to the west alcove have reported that they felt an increase in heat, however, they could not see the actual fire. Soon after the first persons had noticed the increase in heat other guests started to smell smoke. This was followed by the first visual observations of the fire. Approximately eight minutes passed from when the fire was first detected until it was visually observed.

When the first visual detection occurred, the fire was confined to a seat in the back of the west alcove, but the rate of spread was fast. It is believed that a combination of seat upholstering of polyurethane foam and PVC covering, the walls lined with combustible material, and the presence of a low ceiling contributed to the rapid fire spread. As the fire began to spread parts of the roller blind that previously had separated the west alcove from the rest of the room was raised. Around this time three doormen, one barman and at least one guest tried to extinguish the fire with manual fire extinguishers. However, these attempts had no effect on the fire. Within two minutes the ceiling, as well as other parts of the room, began to collapse and flames began to shoot into the rest of the room. At this point the disc jockey lowered the music and said:

> "We have a slight problem, don't panic. Walk on to the nearest exits."
> (Keane, 1982, p. 95)

Following the disc jockey's announcement most of the guest started to move towards the exits. Congestion arose, particularly at the main entrance, which the majority of the guests had chosen as their exit. Now, approximately four minutes after the first visual observations of the flames, the fire in the west alcove was fully developed and all its contents were on fire.

Evacuation had been initiated too late in order for all of the attending guests to reach an area of safety before untenable conditions were reached. Many of the guests appear to have realised the severity of the fire too late and instead of making an effort to evacuate they seem to have watched the fire and the extinguishing attempts with interest and curiosity. This is illustrated in the following statement from the Tribunal of Inquiry's report:

> She saw what seemed to her to be a very small fire on the seat in Tier 9 of Row B. It seemed to her to be a fire which was easily controllable. (Keane, 1982, p. 68)

Furthermore, one of the doormen that tried to extinguish the fire have reported that:

> As he turned to leave the alcove, he also saw that people were standing in front of the fire and he shouted to them to "get the hell out of there". (Keane, 1982, pp. 77-78)

The Tribunal of Inquiry concluded that a prompt and efficient evacuation did not take place because a majority of the guests tried to leave by the main entrance, some of the other exits were either locked or partly blocked and staff had not received any training on how to cope with such a situation. Furthermore, the rapid speed of the fire created untenable conditions in the means of egress in very short time. However, the fact that many of the guests appear to have watched the fire in the west alcove without making any attempts to evacuate most certainly contributed to the inefficient evacuation as well. Instead of interpreting the fire as a serious risk it was interpreted as a small and controllable fire and this delayed the evacuation.

1.1.2. The Fire at Bradford City Football Ground

On 11th May 1985, a fire broke out during a football match between Bradford City and Lincoln City. The fire started forty minutes into the game in the west stand, holding about 2000 people, of the arena, and was probably caused by an accidentally dropped match which ignited combustible rubbish, such as sweet papers, cigarette butts and dead matches that had accumulated in a void under the stand for some time. The fire claimed the lives of 56 people and injured approximately 265 (Bradford City Football Club, 2010; Canter, Comber, & Uzzell, 1989; Rasbash, et al., 2004; Sime, 1999).

The sequence of events on the day of the fire have been summarized by Canter et al. (1989) and is presented in Table 1.1.

Table 1.1. Sequence of events during the fire at Bradford City Football Ground. Reproduced from Canter et al. (1989).

Time	Minute	Fire	Events	Smoke	Escape
15.40	0	Ignition of rubbish	Smell of burning		
15.41	1	Serious waste fire – 0.1 MW			
15.42	2	Burning of timbers beneath floor			
15.43	3	Flames above floor	Call to brigade		Serious local escape
15.44	4	Flame above floor (several m^2)	TV commences	Serious problem in back corridor	Main escape precipitated
15.45	5	Flame under roof (fire at floor level about 10 m^2)		Substantial parts of back corridor blocked and lethal	
15.46	6	Serious spread under roof and involving roof	Fire Brigade arrives		
15.47	7	Stand completely alight			

As can be seen in Table 1.1 the fire spread rapidly. The west stand was made of wood, it had wooden seating in the back and propylene seating on concrete in front of that. In combination with the rubbish that had accumulated over time in the void beneath the stand the total fire load was high and the choice of material contributed to the fast fire growth. Furthermore, because the football ground was located outside there was an unlimited amount of oxygen to support the fire.

Two spectators who felt that their feet and legs were getting warm made the earliest observations of the fire. When they looked down they could see glow of a small fire inside the void beneath the stand. However, in the initial stages of the fire the spectators close to the fire did not take it very seriously; they moved away and continued to watch the match. It was first when the flames were several metres above the floor that the majority of the spectators initiated evacuation. By then, the time required to reach an area of safety before untenable conditions were reached was to short.

Many of the spectators chose to evacuate through a corridor running at the back of the stand, i.e., the same way they had entered the stand. The corridor had exits leading onto the street, however, many of them were closed and some locked. The open exits could consequently not accommodate the number of spectators that tried to exit the stand that way and a majority of the deceased were found near those exits.

1.1.3. Conclusions
The two fires presented above represent fire scenarios in which the fire growth was very rapid. They may not be representative fires, but they do, however, suggest that building occupants not always take the initial events of a fire very seriously. In both incidents the flames were clearly visible, but nevertheless it took the occupants a couple of minutes before they decided to evacuate. The postponed evacuation was in neither fire the sole factor contributing to the many deaths. This is seldom the case in larger catastrophes involving fire. However, it effectively reduced the time available to reach an area of safety before untenable conditions were reached.

1.2. Theories of Human Behaviour
In the section above it is demonstrated that building occupants not always take the initial events in a fire very seriously. In both the Stardust Club fire and the fire at the Bradford City Football Ground this consequently postponed the evacuation. However, no explanation of why the fires were not taken seriously has been given. This is because a deeper understanding of human behaviour in fire is required if the question *why* is to be answered.

One way to gain knowledge about human behaviour in fire is to study the theories and models that have been developed by researchers. These models can be used not only to explain the outcome of an incident, but also to predict the behaviour of building occupants in a fire in the design process of new buildings, something that has become very important due to the worldwide movement toward performance based codes. Theories and models of human behaviour have evolved much during the last years and today it is known that the total evacuation time does not equal the time it takes building occupants to move from A to B. Consideration must also be given to the activities that are performed after a fire has been detected, prior the actual movement. In fact, these activities often take longer time to perform than the time it takes to move to a safe area (Proulx, 2001; Purser & Bensilum, 2001).

A model widely used by engineers in the fire safety design process is the egress time model presented in Figure 1.2 (Proulx, 2008). The model suggests that a comparison should be made between the *available safe escape time* (ASET) and the *required safe escape time* (RSET). Basically the time between ignition of a fire and the time at which all occupants can reach an area of safety should be shorter than the time between ignition of a fire and the time at which a tenability criterion is reached. Although the egress model is a valuable tool in the fire safety design process it provides limited guidance towards the understanding of human behaviour. It does only describe how the behavioural aspects shall be considered in the design process, and hence should not be used to describe human behaviour in fire. Thus, there is a need to study other models of human behaviour in fire.
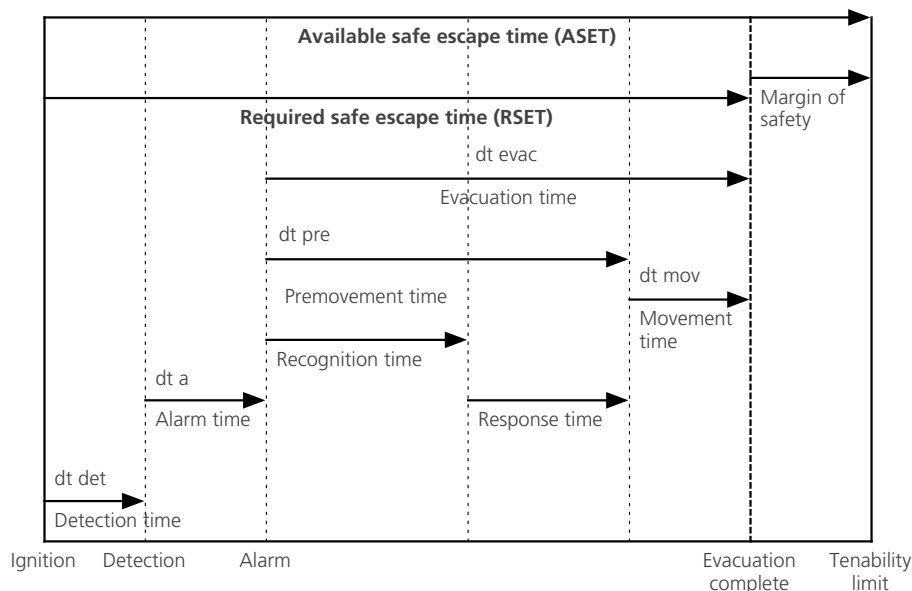

Figure 1.2. The egress time model. The RSET should be shorter than the ASET. Reproduced from Proulx (2008).

1.2.1. Behaviour Sequences

The two first major studies on human behaviour in fire were carried out in the 1970s (J. L. Bryan, 1999; Kobes, Helsloot, de Vries, & Post, 2010). The first study was carried out in Great Britain by Wood (1972), who developed a standard questionnaire which was used by fire-fighters to interview individuals involved in a fire about their experiences. A total of 2139 individuals were interviewed in the study. The second study, similar to the first one, was carried out by Bryan (1977) in the United States a few years later. His study included 584 individuals who had been involved in a fire. Despite cultural differences it was, among other things, concluded in both studies that family members tend to re-enter a building after they have initially escaped from it, that people tend to walk through smoke when evacuating and that people in residential fires try to extinguish the fire. Furthermore, the studies concluded that panic seldom emerged in the fire incidents that were studied. The two studies revolutionized the understanding of human behaviour in fire at that time and do still today constitute the foundation of human behaviour theories.

A couple of years later Canter, Breaux and Sime (1980) performed a similar study and demonstrated that human behaviour in fire can be divided into different behaviour sequences. To

aid the understanding of human behaviour in fire a behaviour sequence model was developed, see Figure 1.3. The model is based on the sequence of actions that occur in a fire and data was collected from past fires in domestic, multiple occupancy and hospital buildings. With the help from local fire brigades the participants in the fires were contacted and interviewed, often at the site of the fire. They were asked to give as detailed an account as possible of everything that had happened from the time they became aware that something was out of the ordinary. Canter et al. (1980) used the data to create diagrams in which the relationships between acts were illustrated, i.e., decomposition diagrams.

It was concluded that characteristic patterns of behaviour occurred in each of the occupancy types that were examined. This resulted in a general model that can be used in the understanding of human behaviour (Figure 1.3). The model demonstrates that human behaviour in fire can be described by three sequence categories, i.e., nodal points: interpret, prepare and act. As the sequence of behaviour unfold, the potential actions increase in variety.
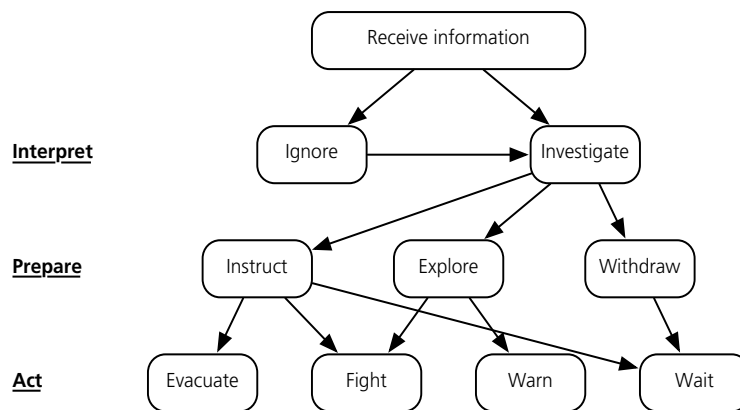

Figure 1.3. The behaviour sequence model developed by Canter et al. (1980), which can be used to explain human behaviour in fire. Reproduced from Canter et al. (1980).

In the early stages of a fire, building occupants will spend time trying to figure out the situation. Information and fire cues are most often scarce and consequently the decisions that a person makes are associated with great uncertainties. This uncertainty is reduced when more information about the fire is received.

Canter et al. (1980) also developed a role-rule model by demonstrating that the way a person responds to fire cues are dependent on a set of expectations that the person has in a particular context. The activates performed in a fire situation are influenced by guiding principles, i.e., rules, linked to the set of expectations a person has (the person's role). It can thus be expected that staff will respond differently to a fire than building visitors, which has also been the case in a number of fires (Donald & Canter, 1990; Fennell, 1988).

The behaviour sequence model should be interpreted as a cycle. Information and fire cues will vary over time and new information is likely to appear over time. Thus, a decision made in the early stages of a fire may later be changed. For instance, a person who has decided to ignore a fire cue, e.g., an alarm bell, may very well re-evaluate that decision when new information is received, e.g., smoke from the fire.

1.2.2. Decision Making in Fire

Decision-making in a fire is based on a person's interpretation of the cues he or she receives. It can be described as an uncertainty reduction, and it is argued that the choice to evacuate is a result of a complex interplay between three factors: physical constraints, personal intentions, and perceptions of the possibilities for coping with the situation (Tong & Canter, 1985).

If a building occupant is to arrive at an appropriate decision in a fire, e.g., to evacuate, he or she must first of all receive information about the fire (Figure 1.3). Secondly, the information about the situation must be interpreted accurately and the risk must be defined to oneself and others. Wood

(1972) argues that a building occupant is likely to answer the following three questions in a fire situation before deciding on an action:

1. If there is a fire, how severe is it?
2. To what degree does it threaten me personally?
3. How soon will it threaten me?

It is not until the situation is defined as a serious risk that it can be expected from a building occupant to arrive at a proper decision on how to act given the fire (Kuligowski, 2008, 2009; McConnell, et al., 2010; Wood, 1972). This behavioural process of occupant response in a building fire is demonstrated in Figure 1.4.
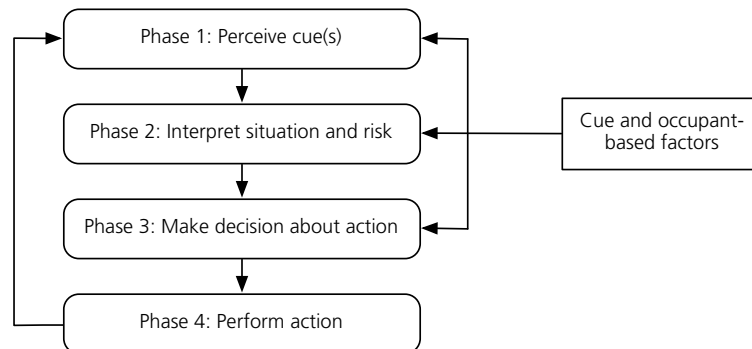

Figure 1.4. Both cue and occupant-based factors will influence the decision-making process in a fire. Reproduced from Kuligowski (2008, 2009).

There are a number of factors influencing the decision-making process in a fire, e.g., factors that influence the perception of the fire cues, the interpretation of the situation, and the decision about what action to take (John L. Bryan, 2008; Kuligowski, 2008, 2009; Proulx, 2001; Purser & Bensilum, 2001). These factors are related to occupant characteristics, building characteristics and fire characteristics. Another way to categorize these factors is to divide them into two main types: cue-based and occupant-based factors (Kuligowski, 2008, 2009). In addition, occupant-based factors can be divided into pre-event and event occupant based factors.

Occupant-based pre-event factors are possessed by the occupant prior the fire situation. Examples are previous experience of fire, knowledge of evacuation routes, age and gender. For instance, research has shown that the likelihood of a fire being perceived decreases with increasing age. However, defining the fire as a risk to oneself and others increases with increasing age. In addition, research has shown that women are more likely to perceive a fire than men, and that they are also more likely to define the fire as a risk to oneself and others. In contrast to the occupant-based pre-event factors, the event factors are possessed by the occupant as a function of the event, and an example is proximity to the fire. For instance, the likelihood of a fire being perceived is increased with increasing proximity to the fire, or if the fire is visually accessible (Kuligowski, 2008, 2009; Proulx & Fahy, 1997; Sime, 1998).

Cue-based factors basically represent the type, number and complexity of the clues related to the event. For instance, it has been demonstrated that if a cue is visual or audible, the likelihood of it being perceived is increased.

1.2.3. Risk and Risk Perception
If building occupants are to arrive at a proper decision in a fire situation, the situation must be defined as a risk. In other words, they must first identify the hazard, i.e., the fire, and then estimate the risk, before arriving at an appropriate decision, i.e., to evacuate. A summary of this risk management process is defined by IEC (2005) and is presented in Figure 1.5.
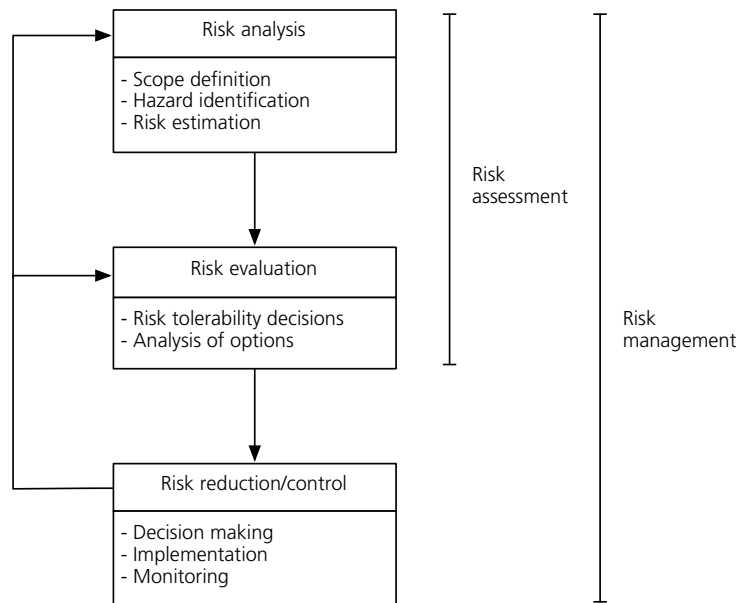
Figure 1.5. The risk management process. Reproduced from IEC (1995).

This report mainly focuses on the upper part of Figure 1.5, i.e., risk assessment. Attention will especially be given to the part of the risk analysis, which includes the risk estimation.

The modern definition of the term risk derives from a technical and objectivistic viewpoint, which originates from a physical viewpoint on risk. This modern definition excludes any subjective estimations of risk. However, the objectivistic viewpoint has received much criticism during the last decades. The critics mean that important social, psychological and cultural factors are excluded when risk is treated as something objective. This has lead to a development of a social constructive viewpoint on risk. There is, however, no commonly accepted definition of the term risk within any of the two groups (Nilsson, 2003).

Renn (1998) argues that although there is a lack of a solid definition, the term risk is often associated with a possibility that an undesirable state of reality may follow natural events or human activities. Kaplan and Garrick (1981) describe the term similarly and argue that it is a combination of uncertainty and damage. Hence, the common denominator in most definitions is (1) the probability of a (2) negative consequence as a result of (3) an event (Nilsson, 2003).

A quantitative method for analysing risks has been suggested by Kaplan and Garrick (1981), who argue that risk should be treated as a set of possible scenarios. Each scenario represents an event in the system that is being studied, and for each scenario there is a possibility and consequence. Somewhat simplified, risk can be described as the set of answers to the following questions:

1. What can happen?
2. How likely is it to happen?
3. If it does happen, what are the consequences?

The quantitative definition of risk is appropriate for technical calculations. However, within the framework of this report a sufficient definition of risk is: *an event, i.e., a fire, that possibly could lead to consequences that have an impact on what people value.*

The social constructivists argue that there is a variation in the perception of risk among people, which means that individuals may interpret the same event differently. This suggests that risk is not an objective estimation of the probability and the consequence of a certain event, but a subjective estimation. Consequently, this also means that the behavioural response due to a risk is guided by the perception and interpretation of the risk, and not the actual value (Enander, 2005; Rundmo & Moen, 2006; Slovic, 2001).

Factors that influence risk perception can be divided into three categories (Enander, 2005):

1. Factors related to the source of the risk, e.g.,
   a. If the exposure to the risk is voluntarily or not
   b. The type and magnitude of the consequence that the risk may cause
2. Factors related to the individual, e.g.,
   a. Previous experience of the risk
   b. Perceived control of the risk
3. Factors related to social and societal issues, e.g.,
   a. Publicity in media

Enander (2005), Riskkollegiet (1993) and Rundmo and Moen (2006) show that differences in risk perception can be found when studying individuals with different demographical background. Among other things the following trends has been acknowledged:

1. Gender
   a. Women's perception of risk is greater compared to men's
   b. Women are more concerned about safety than men
2. Age
   a. With increasing age, the interest of risk and safety issues is increased
   b. With increasing age, the perceived vulnerability is increased

1.3. Subjective Estimation of Fire Growth

Previously it was mentioned that the likelihood of a fire being perceived increases when a person is close to the fire, or if it is visually accessible. However, the observations from the past fires discussed in section 1.1 suggest that the fires were not necessarily interpreted as a risk. One explanation could be that the rate of fire growth was underestimated in both fires. By underestimating the fire growth, a fire may not be interpreted as a risk, which evidently will delay evacuation.

The initial stages of a fire is typically characterized by an accelerating heat release rate, i.e., an accelerating fire growth (Karlsson & Quintiere, 2000). This accelerating growth can be described with a mathematical expression where the heat release rate increases as the square of the time:

$$\dot{Q} = \alpha \cdot t^2$$

where
α is the growth factor [kW/s^2]
t is the time from established ignition [s]

This relationship, where the fire is assumed to grow exponentially in the initial stages, is a simplification of reality but has been demonstrated to agree well with real fires. However, the observations from the Stardust Club fire and the fire at the Bradford Football Stadium suggest that the subjective estimation of the fire growth may not agree with the objectively calculated value.

Subjective estimation of fire growth was examined in the 1980s, in an experiment carried out by Canter, Powell and Booker (1988). A set of 7 photographs taken at different stages of a fire were shown to test participants, who were asked to estimate the difference in time between each paired combination of the set of photographs. Twenty test subjects participated in the experiments, namely 10 researchers and 10 domestic or secretarial staff. The test results revealed that all the test participants underestimated the rate of growth of the fire by overestimating the time between the set of photographs. The results indicated that people in general are capable of judging the rate of minor changes in growth. However, when the predictions involve lateral fire spread and/or smoke production, people's capabilities are not as good.

Although the study by Canter, Powell and Booker (1988) revealed a very interesting problem, the study is not very transparent and it has some shortcomings. First of all, the growth rate of the fire demonstrated in the photos is not explicitly stated. Obviously the fire must have been growing, otherwise no conclusions regarding subjective estimation of the fire growth would have been able to

draw. Furthermore, the test participants were shown all 7 photographs at the same time, and based on their estimations a cumulative time scale was produced. It is likely that the test participants started by arranging the 7 photographs in order, and then estimated the time lapsed between the different paired combinations. This means that an overestimation of the time in the early stages of the fire would lead to overestimations in the later stages.

The perceived severity of the fire and the rate of which it is expected to grow, i.e., the risk, is a critical factor, which evidently determines the premovement time in an evacuation (Canter, et al., 1988). The discussion in this chapter do, however, imply that people in general may not be very good at predicting fire growth, especially not in the early stages. This is also argued by Proulx (2001) and Kobes et al. (2010) who states that our beliefs and assumptions regarding the speed of fire and smoke growth, i.e., the development of fire, is often incorrect.

The experiment carried out by Canter et al. (1988) had its shortcomings and included a rather small population. In addition, technology has advanced much since their experiments. For instance, a similar experiment would today be possible to carry out using film sequences instead of static photographs, which would increase the degree of realism. Another interesting aspect to consider is whether or not there are demographic differences in the means of perception of fire growth, e.g., between men and women, and young and old.

1.4. Problem Formulation
The problem formulated for this master's thesis is:

- Are people in general capable of defining the severity of a fire in its early stages?

The question can be broken down into smaller questions:

- Does a person's subjective estimation of fire growth correspond with the actual fire growth?
- Does a person's perceived ability to extinguish a fire with a portable fire extinguisher correspond with the theoretical ability?
- In terms of defining the severity of a fire in its early stages, are there differences between:
  - Men and women?
  - Young and old?

1.5. Research Objectives
The purpose of this study is to investigate how people in general perceive the rate of fire growth when the fire is visually accessible. The purpose is also to study people's perceived ability to extinguish a fire with a portable fire extinguisher. The goal is to develop the understanding of human behaviour in fire by answering the questions presented in section 1.4.

1.6. Target Audience
The target audience of this report are engineers and researches in the field of fire protection engineering. In addition, this report will likely be valuable to other people working with design of buildings.

1.7. Delimitations
Human behaviour in fire is a complex process involving decision-making under stress, see Figure 1.3 and Figure 1.4. In addition, there are many factors influencing a person's response to a fire, i.e., cue and occupant based factors. This study focuses on people's ability to predict fires that are visually accessible. A delimitation of the study is hence that no consideration is taken to other factors, e.g., reactions related to the smoke propagation from fires or the smell of smoke. It is most likely that these factors also contribute to the overall perception of fire and the risk, but it would not be possible to perform this type of study taking these into consideration.

2. Method

A questionnaire including film sequences of fires was created to collect data on people's estimation of fire growth and their perceived ability to extinguish fires. The questionnaire was projected on a screen in front of the participants, and they were then asked to answer the questions onto a paper version of the questionnaire. The method was adopted from Fridolf and Nilsson (2010).

In the following sections the methods for recruiting participants, creating the questionnaire and collecting the data is presented. Finally, the statistical methods used for analysing the data are presented.

2.1. The Participants

A total of 535 persons took part in the study, namely 304 men and 231 women, see Table 2.1. The selection of the participants were deliberately selective, and was made so that the participants represented young and old, men and women and people with different academic background. This was done to enable an analysis of demographic differences.

Table 2.1. A description of the participants in the study. PRO and SPF are organizations for senior citizens.

Type	Association	Number	Men / Women	Age interval
Students	Faculty of Engineering and Lund University	406	256 / 150	18-57
Employees	IKEA	60	24 / 36	23-65
Employees	Lund University School of Economics and Management	7	3 / 4	27-65
Senior citizens	PRO in Malmö	54	16 / 38	47[1]-88
Senior citizens	SPF in Lund	8	5 / 3	69-86

The data was collected in groups at 19 different occasions, where the number of participants varied from 8 to around 60, with one exception for the employees at Lund University School of Economics who was shown the questionnaire individually.

2.2. The Questionnaire

The questionnaire was created in Apple's Keynote ´09, version 5.0.4 (633), and was divided into three parts. In the first part of the questionnaire the participants were asked to estimate the time differences between two film sequences of the same fire. In the second part of the questionnaire the participants were asked about their perceived ability to extinguish a fire with a portable fire extinguisher. In the third part of the questionnaire the participants were asked general questions about their age, gender and academic background. The Keynote-version of the questionnaire is presented in Appendix 1, and a paper-version of the questionnaire is presented in Appendix 2.

Before each study was initiated the participants were asked to sit down in front of a screen. They were told the purpose and the goal of the study, and they were asked to leave their own answers without discussion the questions with the person sitting next to them. They were also informed that participation was voluntary, and that their answers would be treated with confidentiality. Thereafter the paper copy of the questionnaire was handed out and the study was initiated. Prior to each section of the questionnaire, the participants were given information and instructions related to that section.

2.2.1. Part 1: Estimation of Time Difference

In order to study subjective estimation of fire growth a method was developed where the participants were shown two film sequences of a fire. The first film sequence was 25 seconds long and included the initial stages of a fire, t_0-t_1 in Figure 2.1. The second film sequence was 3 seconds long, and represented a later stage in the fire development, t_2-t_3 in Figure 2.1. The participants were asked to estimate the time difference (Δt) between the last frame of the first film sequence, and a looped version of the second film sequence, i.e., t_1-t_2 in Figure 2.1. They were asked to provide

---

[1] Early retired persons included

their answer in minutes and seconds. The film sequences in the questionnaire represented fires in their initial stages, i.e., fires that were growing according to the $\alpha \cdot t^2$-expression. Overestimation of the time difference hence corresponds to an underestimation of the fire growth. In the same way; underestimation of the time difference corresponds to an overestimation of the fire growth.
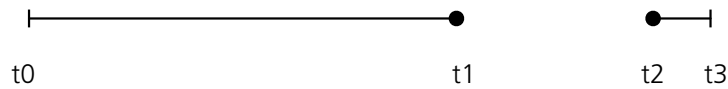

Figure 2.1. A figure demonstrating the timeline of the film sequences shown to the participants.

All of the participants were shown film sequences of two different fires, one representing a fast fire growth and one representing a slow fire growth. The fire representing the fast fire growth was a fire in a rack filled with popcorn, much like the ones used in cinema theatres, and the fire representing the slow fire growth was a fire in a stack of chairs. The fires are discussed in a separate section, see section 2.3.

A total of six versions of the questionnaire were used, in which the order of the fires and the time difference between the first and the second film sequence were varied, i.e., t_1-t_2 in Figure 2.1. The different versions of the questionnaire are presented in Table 2.2.

Table 2.2. The six versions of part 1 of the questionnaire that was presented to the participants. All times are given in seconds.

Version	First shown fire					Second shown fire				
	Type	t_0	t_1	t_2	Δt	Type	t_0	t_1	t_2	Δt
1	Chair	300	325	340	15	Popcorn	0	25	85	60
2	Chair	300	325	370	45	Popcorn	0	25	65	40
3	Chair	300	325	420	95	Popcorn	0	25	40	15
4	Popcorn	0	25	40	15	Chair	300	325	420	95
5	Popcorn	0	25	65	40	Chair	300	325	370	45
6	Popcorn	0	25	85	60	Chair	300	325	340	15

To explain the first part of the study, a test example was demonstrated to the test participants after the instructions had been given. In the test example a film sequence of a person walking in a corridor was shown, see Appendix 1. The participants were then shown a looped film sequence of the person walking in the same corridor, but at a later stage, and asked to estimate the time lapsed between film sequence 1 and 2. In other words, they were asked to practice the method in the test example. The main purpose of this was to minimize misinterpretations and to ensure that everyone had understood what was expected from them, i.e., to increase the reliability of the study.

2.2.2. Part 2: Perceived Ability to Extinguish a Fire
In order to study the participants perceived ability to extinguish a fire, a method was developed where the participants were shown a looped film sequence of a fire. As they were watching the fire they were asked the following question [translated from Swedish]:

> *Do you believe that you would be able to extinguish the fire shown on the left with the portable fire extinguisher in the picture on the right (a 6 kilogram powder extinguisher)?*

In addition, they were orally instructed to assume that the extinguisher was available to them and that they would arrive on the exact time of the sequence shown to them. They were asked to provide their answer by checking one of the following alternatives: *yes*, *no* or *do not know* [translated from Swedish].

Each participant watched two fires, namely the popcorn fire and the chair fire. As in the first part of the questionnaire, a total of six versions of the second part of the questionnaire were used. In each version the order of the fires and the time from ignition, i.e., the fire time, was varied, see Table 2.3.

Table 2.3. The six versions of part 2 of the questionnaire that was presented to the participants. Fire time indicates the time from ignition of the fire. All times are given in seconds.

Version	Fire 1		Fire 2	
	Type	Fire time	Type	Fire time
1	Chair	370	Popcorn	40
2	Chair	570	Popcorn	40
3	Chair	570	Popcorn	85
4	Popcorn	40	Chair	370
5	Popcorn	85	Chair	370
6	Popcorn	85	Chair	570

2.2.3. Part 3 – General Questions

General questions regarding the participants were asked in the third part of the questionnaire. The questions were related to age, gender and academic background and were asked to enable the analysis of differences between young and old, men and female, and people with different academic background.

2.3. The Fires

As previously mentioned, two fires were used in the questionnaire, namely a popcorn fire and a chair fire, the former representing a fast fire growth and the latter a slow fire growth. Both scenarios were set up in a fire lab at Lund University. The fires were filmed and the heat release rate was recorded by measuring the amount of oxygen in an oxygen consumption calorimeter. The heat release rate curve was adjusted so that consideration was given to the smoke travel time in the smoke exhaust hood.

2.3.1. The Chair Fire

The heat release rate curve for the chair fire is presented in Figure 2.2. Pictures showing the fire at the different stages used in the questionnaire, see Table 2.2 and Table 2.3, are presented in Figure 2.2.

Figure 2.2. The heat release rate as a function of time for the chair fire.

| t = 325 s | t = 320 s | t = 370 s | t = 420 s |

Figure 2.3. Different stages of the chair fire.

2.3.2. The popcorn fire

The heat release rate curve for the popcorn fire is presented in Figure 2.4. Pictures showing the fire at the different stages used in the questionnaire, see Table 2.2 and Table 2.3, are presented in Figure 2.5.
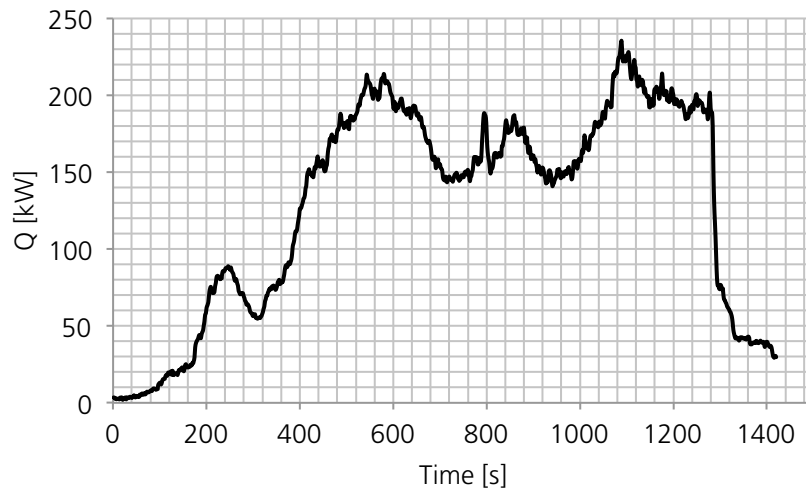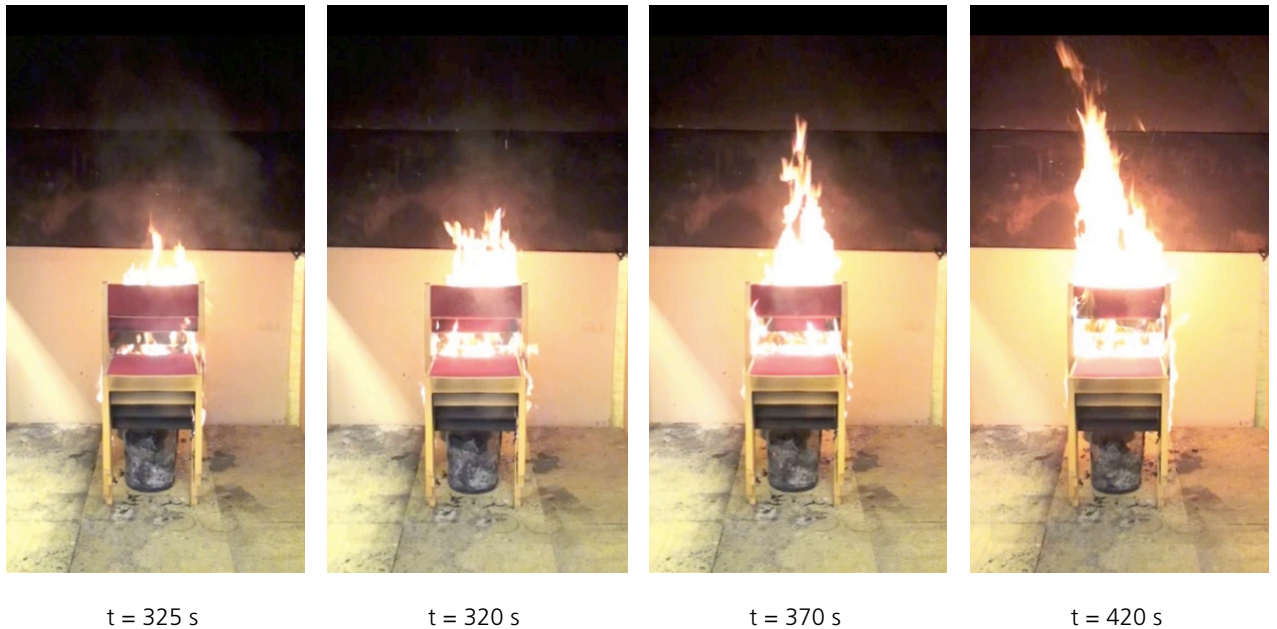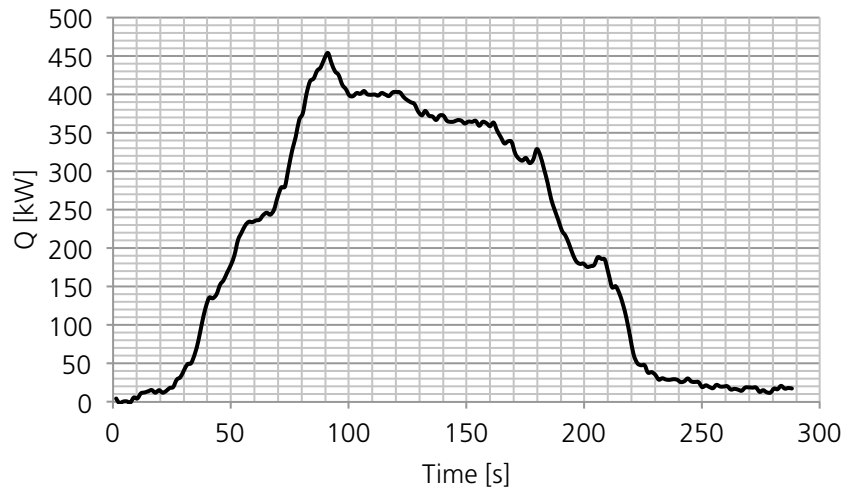

Figure 2.4. The heat release rate as a function of time for the popcorn fire.
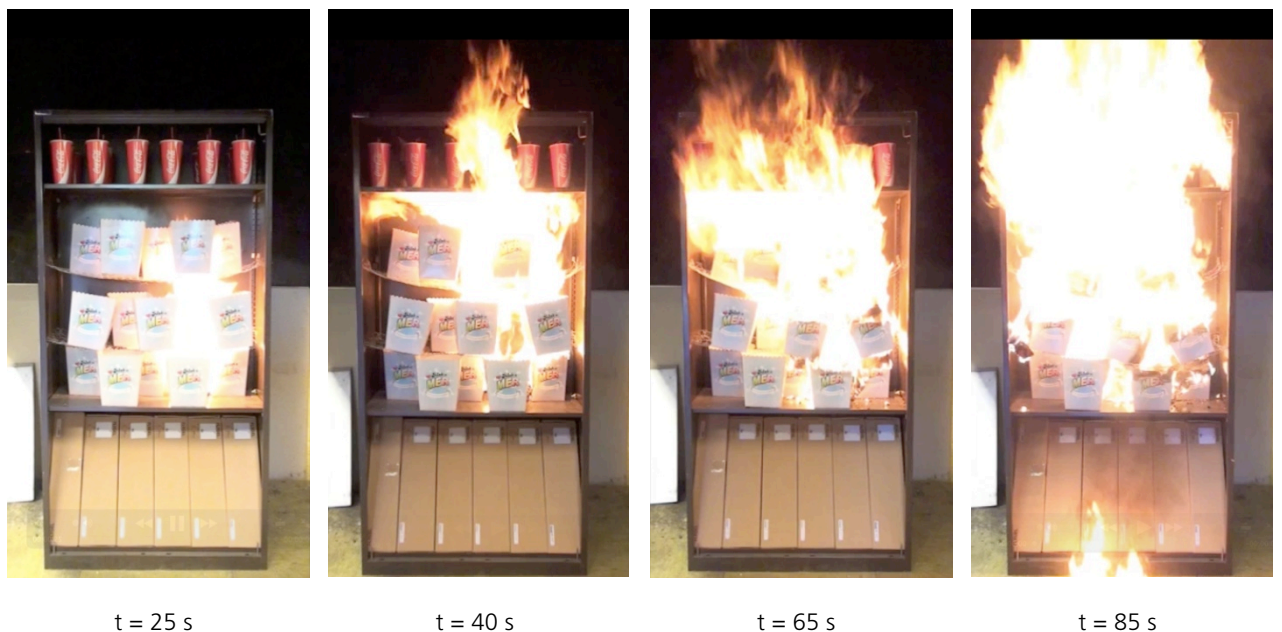

| t = 25 s | t = 40 s | t = 65 s | t = 85 s |

Figure 2.5. Different stages of the popcorn fire.

2.4. Pilot Test

Before the study was initiated the questionnaire was pilot tested on two persons who answered the questions in the same way as in the real study. The main difference was that the test persons orally presented their emotions and thoughts as they answered the questionnaire (Foddy, 1993). This was done in order to ensure the reliability and the validity of the study.

The questionnaire shown to the two test persons included all three variations of both the popcorn fire and the chair fire, see Table 2.2. Thus, the two test persons had to make a total of six estimations of Δt, instead of two. This was the original idea, and it would have maximized the data collection. However, it was noted that the two test persons adopted a comparative methodology when they estimated Δt. In other words, the estimation of Δt for the second and the third fire of the same type were based on the first estimation. Both test persons tried to remember if the fire they

had previously seen was bigger or smaller. The second and the third answer were hence based on the first answer. This meant that the results had not been able to use to answer the problem formulated in section 1.4, and it was therefore decided to only include one film of each fire in the real study.

2.5. Statistical Analyses
Statistical analyses have been performed in order to draw conclusions about the answers provided by the test participants. The analyses can be performed in two ways, either as parametric or as non-parametric. A parametric approach demands that the observations, i.e., the data, are normally distributed or that the sample is large enough. In addition, the parametric approach demands that the data can be classified into at least interval scale. The requirements for a non-parametric analyse are somewhat lower, but in return the outcome of a non-parametric analyse does not offer the same level of detail (Körner & Wahlgren, 2006). In this study both parametric and non-parametric methods are used. A significance level of 5% is used in all of the statistical tests.

2.5.1. Part 1: Estimation of Time Difference
In the first part of the study the test participants were asked to estimate the time between two film sequences, Δt. Estimations of Δt were made for all stages of each fire, i.e., at three stages for the popcorn fire and at three stages for the chair fire, see Table 2.2, Figure 2.5 and Figure 2.3.

The mean estimation of the time difference, $\overline{\Delta t}$, as well as the standard deviation, s, can be calculated for each stage. Consequently, the confidence interval, CI_{95}, can be calculated for all of the stages shown to the participants. This was done with equations 1-3.

$$\overline{\Delta t} = \frac{\Delta t_1 + \Delta t_2 + \Delta t_3 + \ldots + \Delta t_i}{n} = \frac{\sum \Delta t}{n} \qquad \text{Equation 1}$$

$$s = \sqrt{\frac{\sum (\Delta t - \overline{\Delta t})^2}{n-1}} \qquad \text{Equation 2}$$

$$CI_{95} = \overline{\Delta t} \pm 1{,}96 \cdot \frac{s}{\sqrt{n}} \qquad \text{Equation 3}$$

where
Δt is the estimated time [s]
s is the standard deviation [s]
n is the number of observations [-]

The estimations are presented as confidence intervals of the test participants' mean estimation for all stages of each fire, with a confidence level of 95%. In addition, the confidence intervals are plotted in a figure together with the actual time.

2.5.1.1 Demographic Differences
An appropriate method for studying demographic differences is to perform a regression analysis. This means that an equation is used to describe the actual observations. This equation can then be used to predict future measurements of the same type. For the purpose of this study a linear multiple regression analysis was considered. However, to perform a linear multiple regression analysis a number of requirements must be met:

1. The observations must be normally distributed
2. The observations at different times must have approximately the same variance
3. The data should be able to describe with a linear relationship

The number of observations is large. Therefore it is argued that the distribution of the observations can be approximated by a normal distribution by means of the central limit theorem, which consequently fulfils the first requirement above (Körner & Wahlgren, 2006). However, early into the analysis it was determined that the second and the third requirement could not be met. Another approach was therefore adopted; yet, this meant that only one variable could be controlled at a

time. For instance, when a comparison was made between men and women's estimations no attention was paid to the possible age differences. Possible differences between groups with varying demographic qualities are still interesting, but the results should hence be interpreted as descriptive and not predictive due to possible interactions between different variables, e.g., gender and academic background.

2.5.1.2 Gender

To study possible differences between men's and women's estimations of Δt, the group means, represented as intervals with a confidence level of 95%, were compared in a so called Z-test for a population mean (Kanji, 2006; Körner & Wahlgren, 2006). The test is valid because the number of observations is more than 30 for each group and test. For all stages of each fire, i.e., three times for the popcorn fire and three times for the chair fire, a null hypothesis as well as an alternative hypothesis was developed. The null hypothesis is that there is no difference between the group means, and the alternative hypothesis is that there is a difference. The hypothesises are described with equations 4-5.

$$H_0 = \mu_m - \mu_w = 0 \qquad\qquad \text{Equation 4}$$

$$H_1 = \mu_m - \mu_w \neq 0 \qquad\qquad \text{Equation 5}$$

Thus, the alternative hypothesis is always two-sided with a significance level of 5%. The test function is given by equation 6.

$$Z = \frac{(\overline{\Delta t}_m - \overline{\Delta t}_w) - 0}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}} \qquad\qquad \text{Equation 6}$$

where
$\overline{\Delta t}$ is the mean value for each group [s]
s is the standard deviation for each group [s]
n is the number of observations for each group [-]

If the calculated Z-value is larger than 1.96 or smaller than -1.96, the null hypothesis should be discarded and a statistical significant difference between men and women is shown.

2.5.1.3 Age

A non-parametric analysis was performed to investigate if age was a parameter that influenced the estimation of Δt, namely a chi-square test for consistency (Kanji, 2006). Instead of comparing the estimation of Δt, the tendency to overestimate or underestimate the time was studied between the groups. The main reason for this was that the number of observations per group not always exceeds 30. The chi-square test was performed for all stages of each fire, i.e., three times for the popcorn fire and three times for the chair fire.

The test participants were divided into three age groups: (1) ≤ 25 years, (2) 26-50 years and (3) $>$ 50 years. In each age group the estimations were divided into two classes: (1) overestimation of Δt or (2) underestimation of Δt. The persons that had made an exact correct estimation of Δt were excluded from the test. Hence, a table similar to Table 2.4 was constructed for all stages of each fire.

Table 2.4. A method for classifying the test participants answers with respect to age.

	Overestimation	Underestimation	Total
≤ 25 years	x_1	$n_1 - x_1$	n_1
26-50 years	x_2	$n_2 - x_2$	n_2
> 50 years	x_3	$n_3 - x_3$	n_3
Total	$x = \sum_{i=1}^{3} x_i$	$n - x$	$n = \sum_{i=1}^{3} n_i$

The hypothesises are described with equations 7-8.

H_0: Overestimation or underestimation of Δt is
independent of age

<div align="right">Equation 7</div>

H_1: Overestimation or underestimation of Δt is
dependent of age

<div align="right">Equation 8</div>

The test function is described with equation 9.

$$\chi_2 = \frac{n^2}{x \cdot (n-x)} \cdot \left\{ \left(\sum_{i=1}^{3} \frac{x_i^2}{n_i} \right) - \left(\frac{x^2}{n} \right) \right\}$$

<div align="right">Equation 9</div>

For this test the degrees of freedom will be 2, which corresponds to a critical value of 5.99 for a significance level of 5%. The null hypothesis of independence between age groups and classes should hence be rejected if the calculated value exceeds 5.99.

2.5.2. Part 2: Perceived Ability to Extinguish a Fire

In the second part of the study the test participants were asked about their perceived ability to extinguish a fire shown in a film sequence with a portable fire extinguisher. The perceived ability was examined for two stages of each fire, see Table 2.3.

The fire extinguisher used in the study was a 6-kilogram powder extinguisher, certified according to the EN-3 ISO-standard. By using a technique where the REMP[2]-value of the powder extinguisher is assumed, the theoretical extinguishing capacity of the extinguisher can be calculated, see equation 10 (Särdqvist, 2006). Therefore the ability to extinguish the fires can theoretically be determined and compared to the test participants' answers.

$$Q = \frac{\dot{m}_e \cdot x \cdot K}{REMP} \cdot \Delta H_{c,f}$$

<div align="right">Equation 10</div>

where
Q is the theoretical extinguishing capacity of extinguisher [W]
$\dot{m}_e$ is the mass flow rate of the extinguishing medium [g/s]
x is an efficiency factor that takes into account incomplete combustion [-]
K is an efficiency factor that takes into account the application of the extinguishing medium [-]
$\Delta H_{c,f}$ is the heat of combustion of the volatiles [J/g]

2.5.2.1 Gender

To study possible differences between men and women's perceived ability to extinguish a fire, a non-parametric analysis was made, namely a chi-square test for consistency (Kanji, 2006; Körner & Wahlgren, 2006).

The test participants were divided into two groups: (1) men and (2) women. For each group the answers were divided into two classes: (1) answered yes and (2) answered no or do not know. The answers no and do not know where merged into one group since it is not likely that a person will try to extinguish a fire if he or she is unsure about his or her ability. Hence, a table similar to Table 2.5 was constructed for all stages of each fire.

Table 2.5. A method for classifying the test participants answers with respect of gender.

	Yes	No	Total
Men	a	b	a+b
Women	c	d	c+d
Total	a+c	b+d	n=a+b+c+d

---

[2] Required Extinguishing Medium Portion

The hypothesises are described with equations 11-12.

H_0: *The perceived ability to extinguish a fire with a portable fire extinguisher is independent of gender*   Equation 11

H_1: *The perceived ability to extinguish a fire with a portable fire extinguisher is dependent of gender*   Equation 12

The test function is described with equation 13.

$$\chi_2 = \frac{(n-1) \cdot (ad - bc)^2}{(a+b)(a+c)(b+d)(c+d)}$$ Equation 13

For this test the degrees of freedom will be 1, which corresponds to a critical value of 3.84 for a significance level of 5%. The null hypothesis of independence between gender and answer is rejected if the calculated value exceeds 3.84.

2.5.2.2 Age

To investigate if age was a factor that influenced the perceived ability to extinguish a fire, a non-parametric analysis was made, namely a chi-square test for consistency (Kanji, 2006). The test is described in section 2.5.1.3. For each group the answers were divided into two classes: (1) answered yes and (2) answered no or do not know. The answers no and do not know where merged into one group since it is not likely that a person will try to extinguish a fire if he or she is unsure about his or her ability.

The hypothesises are described with equations 14-15.

H_0: *The perceived ability to extinguish a fire with a portable fire extinguisher is independent of age*   Equation 14

H_1: *The perceived ability to extinguish a fire with a portable fire extinguisher is dependent of age*   Equation 15

3. Results

In the previous chapter it was explained that a total of 6 versions of the questionnaire were used in the study, see Table 2.2 and Table 2.3. In each questionnaire the order of the questions, i.e., the fires shown to the test participants were varied in both the first and the second part of the questionnaire. This was mainly done to minimise the effect of the questionnaire design. In addition, the 6 versions of the questionnaire were evenly distributed between the students, employees and senior citizens that participated. In Table 3.1 the number of participants that filled out each of the six versions of the questionnaire is presented.

Table 3.1. Number of participants who filled out each of the six versions of the questionnaire.

Version	Number of participants
1	74
2	73
3	56
4	110
5	115
6	107
Σ	535

In this chapter the test participants' answers are presented and analysed. The first section includes the answers related to the estimation of Δt. In the second section the test participants' perceived ability to extinguish a fire are presented.

3.1. Part 1: Estimation of Time Difference

All of the test participants made one estimation of the time difference, Δt, for each fire, i.e., one estimation of Δt for the popcorn fire and one for the chair fire. Because the questionnaire was available in six versions all test participants did not estimate the same Δt for each fire. In Table 3.2 the number of estimations for each stage of the different fires are presented. In addition, the number of exact correct estimations are included.

Table 3.2. Number of estimations for each stage of the fires shown to the test participants. The number of exact correct estimations are included.

Type	Δt [s]	Number of estimations	Number of exact correct estimations
Chair	15	182	12 (7%)
Chair	45	187	4 (2%)
Chair	95	166	0 (0%)
Popcorn	15	166	21 (13%)
Popcorn	40	187	4 (2%)
Popcorn	60	182	12 (7%)

Figure 3.1 and Figure 3.2 show the estimated time, i.e., t_1 plus the estimation of Δt, for the different real times, i.e., t_1 plus Δt. The error bars represent the confidence interval with a significance level of 95%. The straight dotted line represents a perfect estimation, i.e., when the estimation of Δt equals the real Δt.
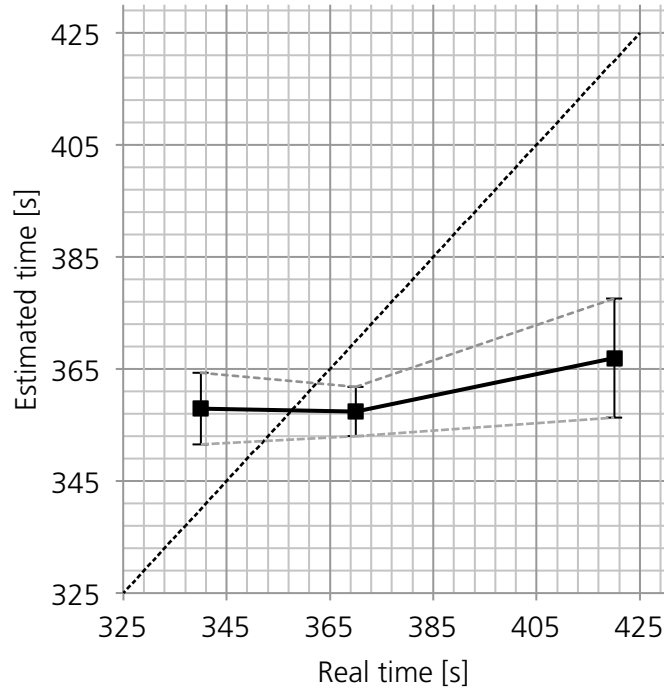
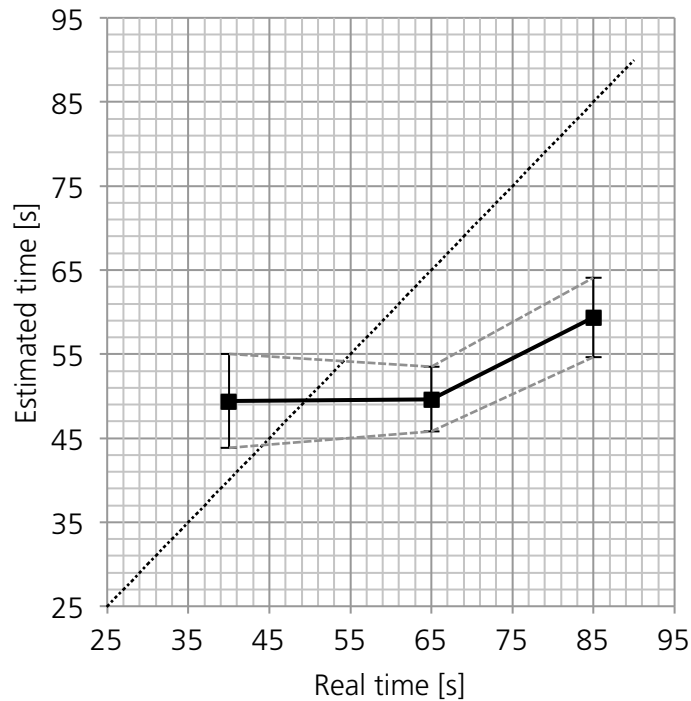Figure 3.1. The estimations of Δt at different real times for the chair fire.

Figure 3.2. The estimations of Δt at different real times for the popcorn fire.

The same trend can be seen for both fires: when Δt is small, i.e., when the time difference between the two film sequences is small, the time is overestimated. Hence, the test participants thus believe that more time has lapsed than what is actually the case. Due to the fact that both fires are growing, this suggests that the fire growth is underestimated. For the two later estimations of Δt it seems as if the situation is reversed, i.e., the time is underestimated, which means that the fire growth is overestimated. It is also noted that the variation around the mean value is relatively small. For the

chair fire the maximum variation around the mean value is 21 seconds, and for the popcorn fire 11 seconds.

3.1.1. Gender

The estimations of Δt are presented for men and women respectively in Figure 3.3 and Figure 3.4. The group means represented as intervals with a confidence level of 95%, is compared in a Z-test for each Δt, see section 2.5.1.2. The data and the results of the Z-test are presented in Table 3.3.
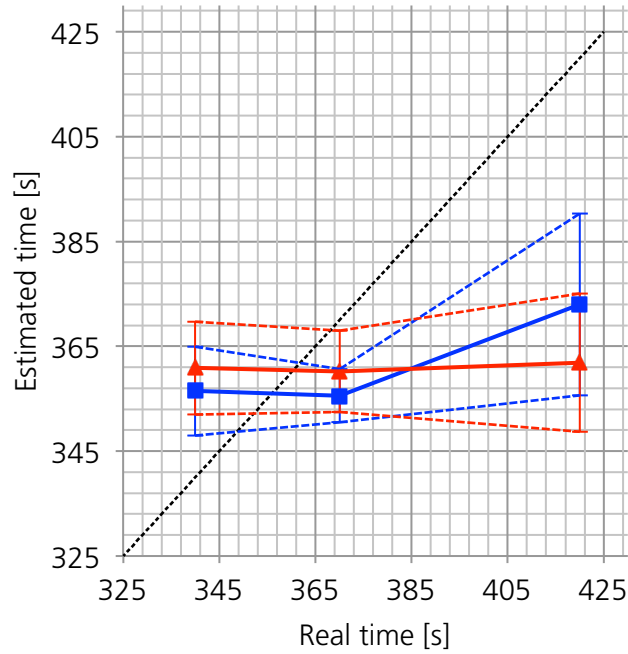

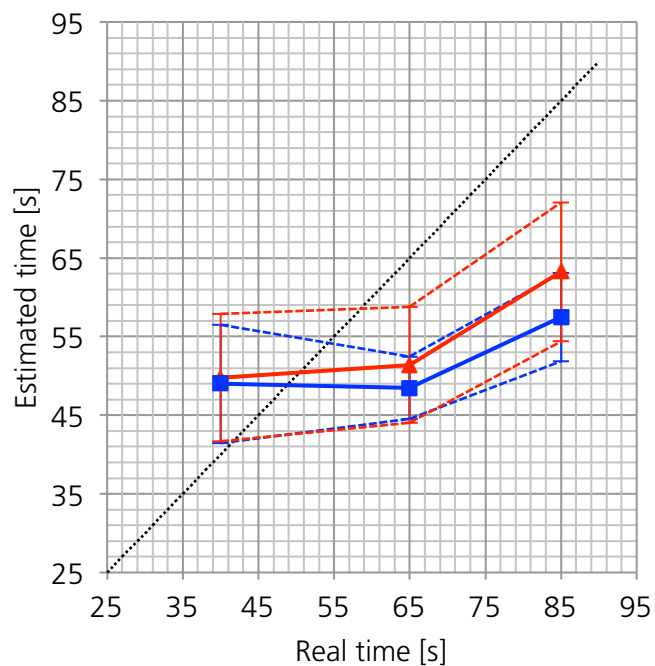Figure 3.3. The estimations of Δt at different real times for the chair fire for men (blue) and women (red).

Figure 3.4. The estimations of Δt at different real times for the popcorn fire for men (blue) and women (red).

Table 3.3. The estimations of Δt at the different real times for both the chair fire and the popcorn fire, presented as Δt + t_1. n = number of test participants for each sample, s = standard deviation for that sample.

Type	$t_2 + \Delta t$ [s]	Men			Women			Z	p
		n	$t_1 + \overline{\Delta t}$ [s]	s [s]	n	$t_1 + \overline{\Delta t}$ [s]	s [s]		
Chair	15	122	356	48	60	361	35	-0.71	0.48
Chair	45	107	356	27	80	360	36	-0.98	0.33
Chair	95	75	373	77	91	362	64	-1.00	0.32
Popcorn	15	75	49	33	91	49	39	-0.14	0.89
Popcorn	40	107	48	21	80	51	34	-0.68	0.50
Popcorn	60	122	57	32	60	63	35	-1.09	0.28

The results reveal that no significant differences can be determined between men and women's estimation of Δt. Both men and women overestimate Δt when it is small, but underestimate Δt when it is larger. The only trend that can be seen is that the underestimation of Δt is smaller for men in the chair fire, however, the situation is reversed when studying the popcorn fire.

3.1.2. Age

The tendency to overestimate or underestimate Δt was examined for different age groups. The estimations of Δt that were exactly correct have been excluded from the statistical test, but are presented in Table 3.1. The number of overestimations and underestimations for each age group is presented for all stages of each fire together with the result of the chi-square test for consistency.

To facilitate the interpretation of the results, a box-plot of each age groups estimation of Δt + t_2 is included. The box represents 50% of the data sample, the remaining 50% is contained within the areas between the box and the whiskers. The single line within the box represents the middle value of the entire sample, i.e., the median. Extreme values that deviate significantly from the rest of the data have been excluded and are instead represented as circles or asterisks.

3.1.2.1   Chair Fire, Δt = 15 seconds

A box-plot for each of the age-groups estimations of Δt + t_1 is presented in Figure 3.5. The number of overestimations and underestimations are presented in Table 3.4.

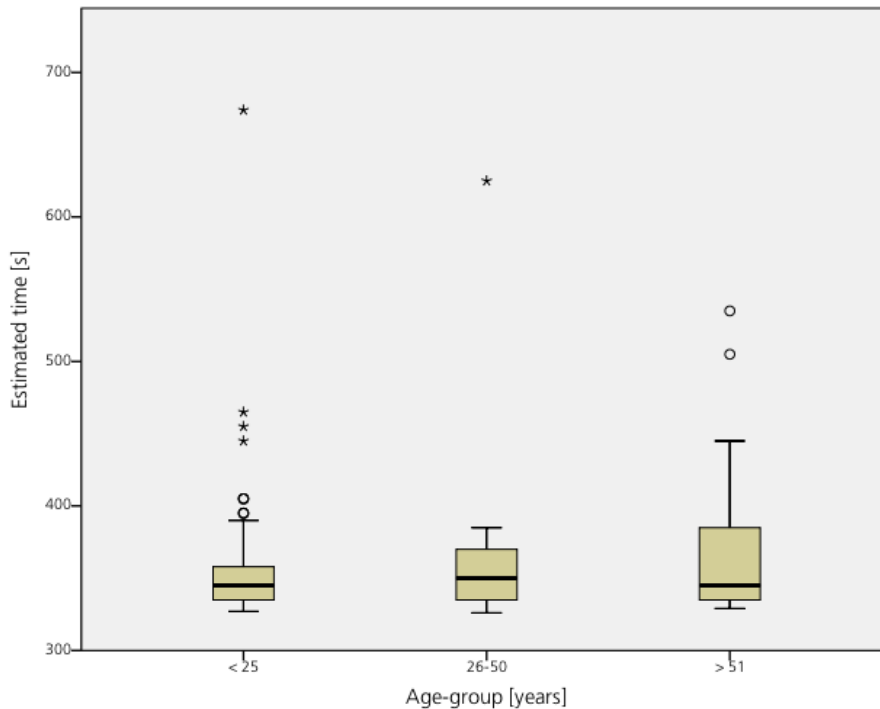

Figure 3.5. Estimations of Δt = 15 seconds represented as box-plots for each of the age groups.

Table 3.4. The number of overestimations/underestimations for each of the age groups.

	Overestimation	Underestimation	Total
≤ 25 years	75	48	123
26-50 years	15	9	24
> 50 years	14	9	23
Total	104	66	170

The result of the chi-square test for consistency suggests that the null hypothesis of independence between the age groups should be accepted (χ_2=0.021, df=2, p=0.99), i.e., the tendency to overestimate or underestimate Δt is independent of age.

3.1.2.2   Chair Fire, Δt = 45 seconds

In Figure 3.6 a box-plot for each of the age-groups estimations of $\Delta t + t_1$ is presented. The number of overestimations and underestimations are presented in Table 3.5.
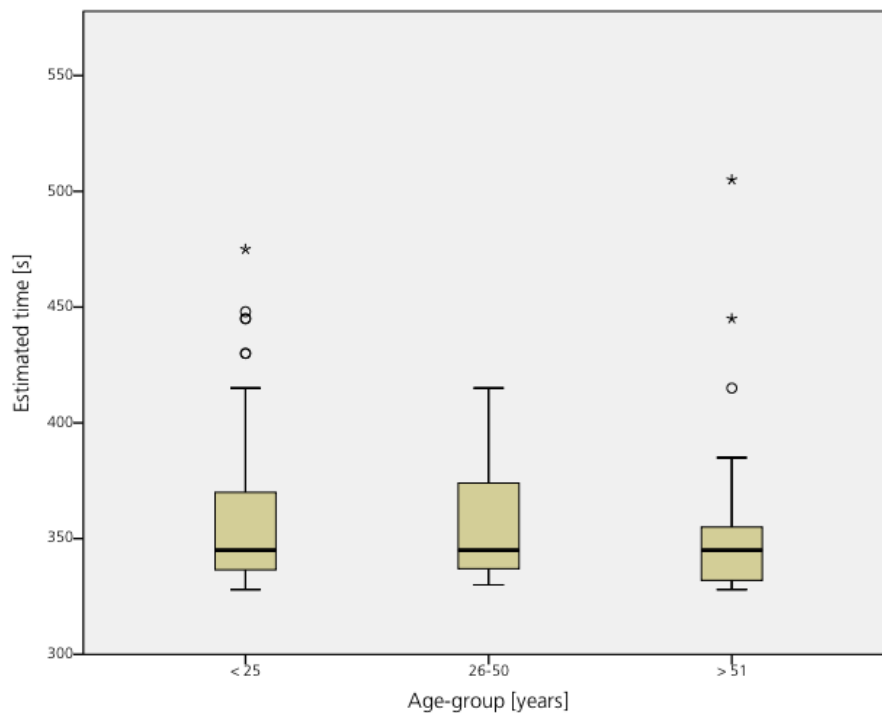

Figure 3.6. Estimations of Δt = 45 seconds represented as box-plots for each of the age groups.

Table 3.5. The number of overestimations/underestimations for each of the age groups.

	Overestimation	Underestimation	Total
≤ 25 years	32	95	127
26-50 years	6	16	22
> 50 years	6	28	34
Total	139	44	183

The result of the chi-square test for consistency suggests that the null hypothesis of independence between the age groups should be accepted (χ_2=0.980, df=2, p=0.61), i.e., the tendency to overestimate or underestimate Δt is independent of age.

In Figure 3.7 a box-plot for each of the age-groups estimations of $\Delta t + t_1$ is presented. The number of overestimations and underestimations are presented in Table 3.6.
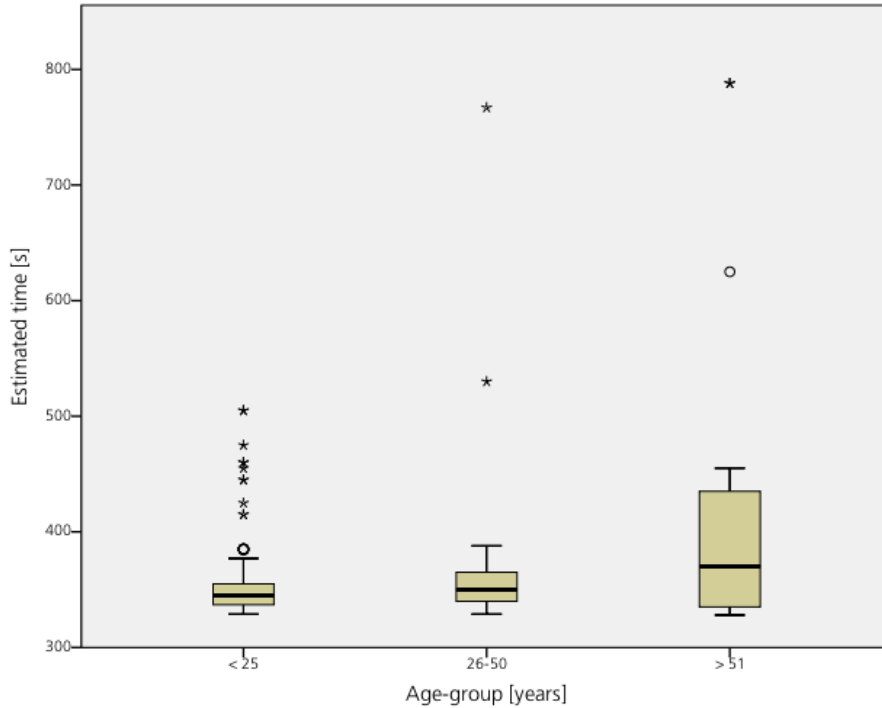

Figure 3.7. Estimations of Δt = 95 seconds represented as box-plots for each of the age groups.

Table 3.6. The number of overestimations/underestimations for each of the age groups.

	Overestimation	Underestimation	Total
≤ 25 years	9	129	138
26-50 years	2	11	13
> 50 years	4	11	15
Total	151	15	166

The result of the chi-square test for consistency suggests that the null hypothesis of independence between the age groups should be rejected (χ_2=7.371, df=2, p=0.03), i.e., the tendency to overestimate or underestimate Δt is dependent of age.

3.1.2.4   Popcorn Fire, Δt = 15 seconds

In Figure 3.8 a box-plot for each of the age-groups estimations of $\Delta t + t_1$ is presented. The number of overestimations and underestimations are presented in Table 3.7.

Figure 3.8. Estimations of Δt = 15 seconds represented as box-plots for each of the age groups.

Table 3.7. The number of overestimations/underestimations for each of the age groups.

	Overestimation	Underestimation	Total
≤ 25 years	48	70	118
26-50 years	9	4	13
> 50 years	10	4	14
Total	78	67	145

The result of the chi-square test for consistency suggests that the null hypothesis of independence between the age groups should be rejected (χ_2=7.807, df=2, p=0.02), i.e., the tendency to overestimate or underestimate Δt is dependent of age. However, 2 of the cells have an expected count of less than 5, which suggests that the result is not very valid, i.e., the test function cannot be approximated to a chi-square distribution.

3.1.2.5   Popcorn Fire, *Δt = 40 seconds*

In Figure 3.9 a box-plot for each of the age-groups estimations of $\Delta t + t_1$ is presented. The number of overestimations and underestimations are presented in Table 3.8.
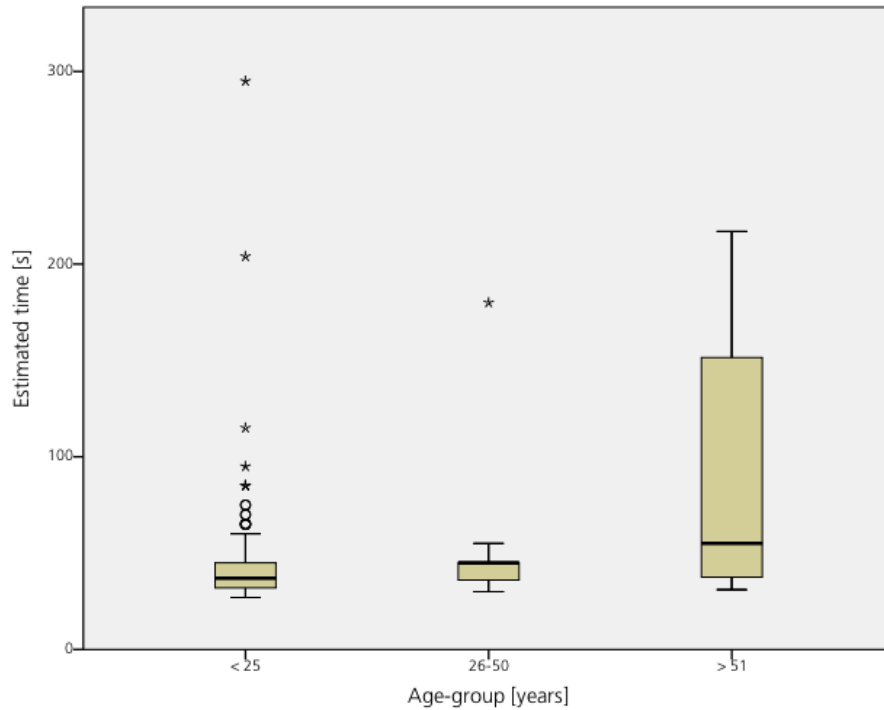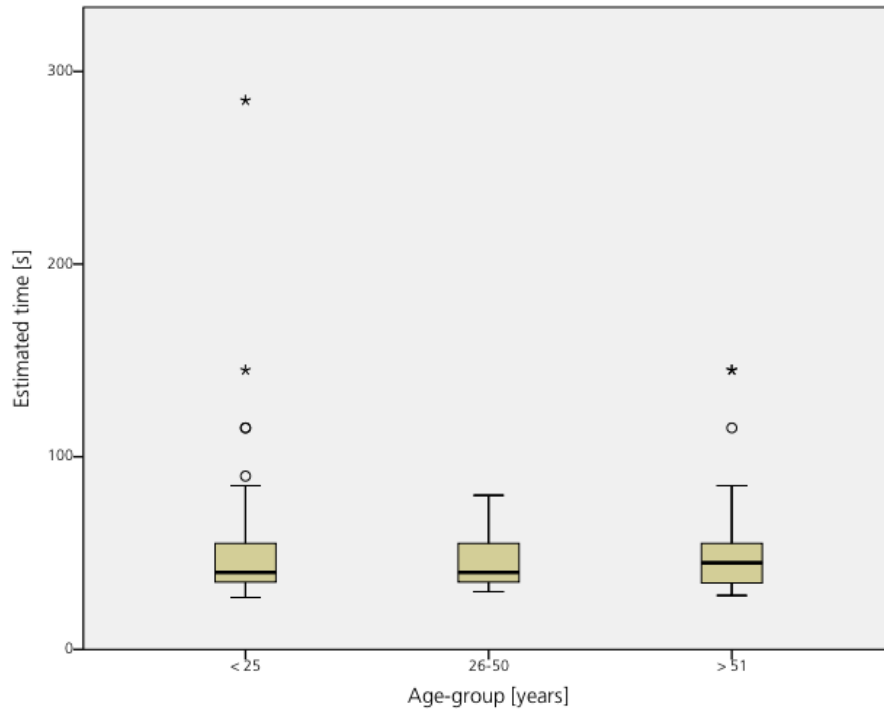

Figure 3.9. Estimations of $\Delta t = 40$ seconds represented as box-plots for each of the age groups.

Table 3.8. The number of overestimations/underestimations for each of the age groups.

	Overestimation	Underestimation	Total
≤ 25 years	19	108	127
26-50 years	2	20	22
> 50 years	6	28	34
Total	156	27	183

The result of the chi-square test for consistency is suggests that the null hypothesis of independence between the age groups should be accepted (χ_2=0.792, df=2, p=0.67), i.e., the tendency to overestimate or underestimate Δt is independent of age.

28

3.1.2.6   Popcorn Fire, Δt = 60 seconds

In Figure 3.10 a box-plot for each of the age-groups estimations of $\Delta t + t_1$ is presented. The number of overestimations and underestimations are presented in Table 3.9.
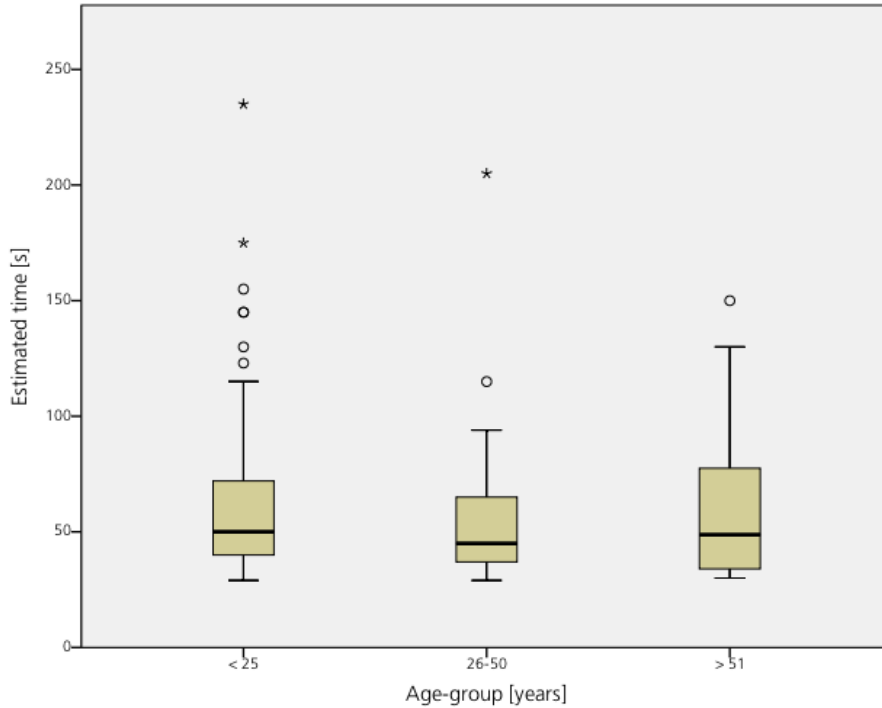

Figure 3.10. Estimations of Δt = 40 seconds represented as box-plots for each of the age groups.

Table 3.9. The number of overestimations/underestimations for each of the age groups

	Overestimation	Underestimation	Total
≤ 25 years	16	108	124
26-50 years	4	20	24
> 50 years	3	19	22
Total	147	23	170

The result of the chi-square test for consistency is suggests that the null hypothesis of independence between the age groups should be accepted (χ_2=0.244, df=2, p=0.89), i.e., the tendency to overestimate or underestimate Δt is independent of age. However, 2 of the cells have an expected count of less than 5, which suggests that the result is not very valid, i.e., the test function cannot be approximated to a chi-square distribution.

3.2. Part 2: Perceived Ability to Extinguish a Fire

The test participants perceived ability to extinguish the different fires are presented in Table 3.10. In the same table the heat release rate is presented for each fire. The results indicate that the popcorn fire is perceived as a greater risk than the chair fire.

Table 3.10.The total number of answers for each stage of the fire.

			Answer			
Type	Fire time [s]	Q [kW]	Yes	No	Do not know	Σ
Chair	370	90	247 (82%)	29 (10%)	23 (8%)	299 (100%)
Chair	570	200	185 (78%)	30 (13%)	21 (9%)	236 (100%)
Popcorn	40	140	152 (59%)	70 (28%)	34 (13%)	256 (100%)
Popcorn	85	430	159 (57%)	87 (31%)	33 (12%)	279 (100%)

Using equation 10, the theoretical extinguishing capacity of the 6-kilogram powder extinguisher used in the study is calculated. The mass flow rate of the extinguishing medium is assumed to be 400 g/s, both efficiency factors 1, and the heat of combustion of the volatiles is assumed to be 40 J/g. The REMP-value for powder varies from 1-4 (Särdqvist, 2006). Assuming complete combustion and a perfect application of the powder, this suggests that the theoretical extinguishing capacity of the extinguisher is 8 MW. Hence, the capacity exceeds all of the fires shown to the test participants. Even is the efficiency factor that takes into account the application of the extinguishing medium is reduced to 0.1, the theoretical extinguishing capacity of the extinguisher still exceeds all of the fires shown to the test participants. This suggests that the 6-kilogram powder extinguisher would be appropriate to use on both fires at any time in Table 3.10.

3.2.1. Gender

A chi-square test of consistency is used to study possible differences between men and women. The categories *no* and *do not know* is merged into one class. The answers given by men and women are presented separately for both fires and for all fire times.

3.2.1.1 Chair Fire, Fire Time = 370 seconds

The result of the chi-square test for consistency is suggests that the null hypothesis of independence between the age groups should be rejected (χ_2=14.546, df=1, p<0.01), i.e., the perceived ability to extinguish the fire with a portable fire extinguisher is dependent of sex. In this case, a greater proportion of the men believe that they can extinguish the shown fire, see Table 3.11.

Table 3.11. The total number of answers given by men and women for the chair fire, fire time = 370 seconds.

	Yes	No	Total
Men	143	15	158
Women	104	37	141
Total	247	52	299

3.2.1.2 Chair Fire, Fire Time = 570 seconds

The result of the chi-square test for consistency is suggests that the null hypothesis of independence between the age groups should be rejected (χ_2=6.045, df=1, p=0.01), i.e., the perceived ability to extinguish the fire with a portable fire extinguisher is dependent of sex. In this case, a greater proportion of the men believe that they can extinguish the shown fire, see Table 3.12.

Table 3.12. The total number of answers given by men and women for the chair fire, fire time = 570 seconds.

	Yes	No	Total
Men	122	24	146
Women	63	27	90
Total	185	51	236

3.2.1.3   Popcorn Fire, Fire Time = 40 seconds

The result of the chi-square test for consistency is suggests that the null hypothesis of independence between the age groups should be accepted (χ_2=5.016, df=1, p=0.03), i.e., the perceived ability to extinguish the fire with a portable fire extinguisher is independent of sex, see Table 3.13. However, notice that 5.016 is very close to the critical value of 5.024, which do suggest that there is a difference between men and women but not within a significance level of 5%.

Table 3.13. The total number of answers given by men and women for the popcorn fire, fire time = 40 seconds.

	Yes	No	Total
Men	71	34	105
Women	81	70	151
Total	152	104	256

3.2.1.4   Popcorn Fire, Fire Time = 85 seoconds

The result of the chi-square test for consistency is suggests that the null hypothesis of independence between the age groups should be rejected (χ_2=15.222, df=1, p<0.01), i.e., the perceived ability to extinguish the fire with a portable fire extinguisher is dependent of sex. In this case, a greater proportion of the men believe that they can extinguish the shown fire, see Table 3.14.

Table 3.14. The total number of answers given by men and women for the popcorn fire, fire time = 85 seconds.

	Yes	No	Total
Men	128	71	199
Women	31	49	80
Total	159	120	279

3.2.2. Age

A chi-square test of consistency is used to study possible differences between different age groups. The categories *no* and *do not know* is merged into one class. The answers given by the different age groups are presented separately for both fires and for all fire times.

3.2.2.1   Chair Fire, Fire Time = 370 seconds

The result of the chi-square test for consistency is suggests that the null hypothesis of independence between the age groups should be rejected (χ_2=7.935, df=1, p<0.01), i.e., the perceived ability to extinguish the fire with a portable fire extinguisher is dependent of age. In this case, it seems as if a greater proportion of young people believe that they can extinguish the shown fire, see Table 3.15.

Table 3.15. The total number of answers given by different age groups for the chair fire, fire time = 370 seconds.

	Yes	No	Total
≤ 25 years	193	34	227
26-50 years	28	5	33
> 50 years	26	13	39
Total	247	52	299

3.2.2.2   Chair Fire, Fire Time = 570 seconds

The result of the chi-square test for consistency is suggests that the null hypothesis of independence between the age groups should be accepted (χ_2=2.368, df=1, p=0.12), i.e., the perceived ability to extinguish the fire with a portable fire extinguisher is independent of age, see Table 3.16.

Table 3.16. The total number of answers given by different age groups for the chair fire, fire time = 570 seconds.

	Yes	No	Total
≤ 25 years	135	34	169
26-50 years	26	6	32
> 50 years	24	11	35
Total	185	51	236

3.2.2.3   Popcorn Fire, Fire Time = 40 seconds

The result of the chi-square test for consistency is suggests that the null hypothesis of independence between the age groups should be accepted (χ_2=2.221, df=1, p=0.14), i.e., the perceived ability to extinguish the fire with a portable fire extinguisher is independent of age, see Table 3.17.

Table 3.17. The total number of answers given by different age groups for the popcorn fire, fire time = 40 seconds.

	Yes	No	Total
≤ 25 years	119	77	196
26-50 years	20	12	32
> 50 years	13	15	28
Total	152	104	256

3.2.2.4   Popcorn Fire, Fire Time = 85 seoconds

The result of the chi-square test for consistency is suggests that the null hypothesis of independence between the age groups should be accepted (χ_2=1.547, df=1, p=0.21), i.e., the perceived ability to extinguish the fire with a portable fire extinguisher is independent of age, see Table 3.18.

Table 3.18. The total number of answers given by different age groups for the popcorn fire, fire time = 85 seconds.

	Yes	No	Total
≤ 25 years	115	90	205
26-50 years	19	9	28
> 50 years	25	21	46
Total	159	120	279

4. Discussion

Theories in human behaviour suggest that building occupants will try to make sense of the situation in the early stages of a fire. This is the reason that people do not initiate evacuation immediately; instead they try to arrive at an appropriate decision on what to do based on the amount of available information. However, in a situation where a fire is visually accessible it could be presumed that building occupants would initiate evacuation rather quickly; there should be no problem for a person to make sense of the situation when the fire is visually accessible. Despite this, past incidents give evidence that even when the fire has been visually accessible to the occupants there has been a delay in evacuation.

In the beginning of this report it was argued that people in general might not be very good at defining the severity of a fire, especially not in the early stages. This could be one of the reasons as to why people do not act on the first sight of a small fire in a building. The focus of this study has therefore been to examine people's ability to predict fire growth. A method was developed where test participants were asked to estimate the time lapsed between two film sequences of the same fire, the first sequence being 25 seconds long and the second 3 seconds long. In addition, the test participants were asked about their perceived ability to extinguish different fires with a 6-kilogram powder extinguisher.

The results from the first part of the study shows that even when the estimations are presented as confidence intervals around the mean value, with a confidence interval of 95%, the line representing a perfect estimation of the time is not included in any case. This suggests that people in general are not very good at predicting fire growth. When estimations are done for a small increase in heat release rate, i.e., a short period of time between the two film sequences, it seems as if the fire growth is underestimated. People thus believe that it takes more time for the fire to develop than what is actually the case. However, when people make estimations of the time between two film sequences where there has been a greater change in heat release rate, estimations are opposite and the fire growth is instead overestimated. Hence, no distinct trend can be seen in the data. This makes it hard to draw any general conclusions about the ability to predict fire growth, i.e., it cannot be concluded that people in general always underestimate fire growth, which was the result of a previous study by Canter et al. (1988). Because the same trend is identified for both fires, i.e., that people tend to underestimate the fire growth when Δt is small, and that people tend to overestimate the fire growth when Δt is large, it is argued that estimation of fire growth is more or less independent of the growth rate of the fire, i.e., α.

The perceived ability to extinguish a fire was also examined in this study. About 80% of the participants believed that they had been able to extinguish the chair fire, and about 60% of the participants believed that they had been able to extinguish the popcorn fire. In theory, it had been possible to extinguish both fires with the extinguisher. This suggests that people are not only poor at predicting fire growth, but also that a many people have problems with defining the severity of a fire.

Possible demographic differences were examined for both the predictions of fire growth and the perceived ability to extinguish a fire with a portable fire extinguisher. In the means of predicting fire growth, no statistical significant differences were identified between men and women at any stage of the two fires. This suggests that men and women are as good/bad at predicting fire growth. In terms of age differences a statistical significant difference was only identified in 1 of 6 cases, which suggests that younger people are as good/bad as older at predicting fire growth. When possible differences between men and women were studied, in the means of perceived ability to extinguish a fire, a statistical significant difference was identified in almost every case. The results thus suggests that when a man is asked about his perceived ability to extinguish a fire, he is more likely to answer yes than a woman. No such trend could be identified when age differences were studied.

In order for occupants to arrive at a proper decision on what action to take in a fire situation, it is a prerequisite that the situation is defined as a risk, i.e., an event that could lead to consequences that have an impact on what people value. An underestimation of the fire growth could hence help

explain why evacuation sometimes is delayed, even when a fire is visually accessible. However, the results presented in this study show no such clear trend. On the contrary it seems as if people in general simply do not know how a fire develops, but guesses. This would suggest that building occupants do not estimate the danger of the situation, i.e., the risk, by predicting the fire growth. Maybe a person only sees the fire for what it is – flames that varies in both height and width, and makes no attempt to predict what will happen in the next 30 seconds. Hence, studies on how a person estimates the danger in a fire situation, and which factors that contributes the most, would be interesting to see in future studies.

Demographic factors that influences the perception of risk was presented in chapter 1. Among other things, age and gender was identified as variables affecting the risk perception. The results in this study reveal almost no such trends. In all cases the estimation of fire growth was more or less the same for men and women, as well as for young and old. However, when the perceived severity of a fire was studied, a difference could be identified between men and women. Since a smaller proportion of women believed they had not been able to extinguish the fires in the questionnaire it suggests that a woman's perception of the risk a fire can create is greater than a man's perception. This is a result that conforms to previous studies in the same field.

The fact that a large proportion, independent of gender, believed that they had not been able to extinguish an extinguishable fire is an implication that must be regarded by practitioners in fire safety engineering. Legislations demand that portable fire extinguishers are installed in buildings, however, it should not be expected that building occupants use these.

4.1. Methodology and Limitations

In this type of study it is necessary to discuss the chosen method, which evidently influences the reliability and the validity of the study. Would the study generate the same results if reproduced, even by another author (reliability), and does the study really measure what it is intended to measure (validity)?

In order to measure people's prediction of fire growths, i.e., subjective estimation of fire growth, a method was developed where test participants were asked to estimate the time lapsed between two film sequences of the same fire. The different stages of the fire shown to the test participants involved the growth-phase, i.e., estimations of the time were made for fires that were growing similar to the $\alpha \cdot t^2$-fire. It is argued that this method is appropriate for the purpose of this study because a person who is good at predicting fire growth would also be good at estimating the time lapsed between consecutive stages of a fire. However, this study has not at all investigated how people estimate time. If the test participants in this study have problems estimating linear relationships, they are most likely to have problems with exponential relationships. The hypothetical scenario method used in this study assumes that people are good at estimating time, and since this is not investigated it does affect the validity of the study in a negative way.

It is argued that the reliability of the study is high. If both the paper-version and the Keynote-version of the questionnaire are designed similar to the ones in this study, and if test participants are provided with the same information as in this study, it is likely that they would provide the same answers. This is based on the fact that over 500 persons participated in this study, which is a relatively large amount of people.

Naturally, the conclusions drawn about the study can only be made for the population that the test participants represent, i.e., students, employees at similar companies to those in this study, and senior citizens. The same goes for the results that have been generated from the statistical analyse in this study. Thus, the reader of this report should have in mind that the results that have been presented are only applicable to the population that the test participants represent. Furthermore, the results should mainly be treated as descriptive, and not predictive.

5. Conclusions

The main conclusion of this study is that people in general are not very good at estimating the severity of visually accessible fires in the early stages. The results of the experimental study suggest that a person's subjective estimation of fire growth does not correspond very well to the actual fire growth, which is either underestimated or overestimated. In addition, the perceived ability to extinguish a fire with a portable fire extinguisher does not correspond to the theoretical ability. It could therefore be argued that the perceived risk of a visually accessible fire not always conforms to the real risk, which in turn could explain why the evacuation of building occupants sometimes has been delayed, even though the fire has been visually accessible. Because the results from this study suggest that the test participants made "guesstimations" rather than estimations of the fire growth, future research should focus on how a person estimates the danger of a fire situation, and which factors that contributes to the perceived risk.

6. References

Bradford City Football Club. (2010). Bradford Fire Disaster. Retrieved 9th September, 2010, from http://www.bradfordcityfc.co.uk/page/History/0,,10266~1013980,00.html

Bryan, J. L. (1977). Smoke as a Determinant of Human Behaviour in Fire Situations (No. NBS-GCR-77-94): University of Maryland, College Park.

Bryan, J. L. (1999). Human behaviour in fire: The development and maturity of a scholarly study area. Fire and Materials, 23(6), 249-253.

Bryan, J. L. (2008). Behavioral Response to Fire and Smoke. In P. J. DiNenno (Ed.), SFPE Handbook of Fire Protection Engineering (Fourth ed.). Quincy, Massachusetts: National Fire Protection Association.

Canter, D., Breaux, J., & Sime, J. D. (1980). Domestic, Multiple Occupancy, and Hospital Fires. In D. Canter (Ed.), Fires and Human Behaviour (pp. 117-136). Chichester: John Wiley & Sons Ltd.

Canter, D., Comber, M., & Uzzell, D. L. (1989). Football in its Place: An Environmental Psychology of Football Grounds. London: Routledge.

Canter, D., Powell, J., & Booker, K. (1988). Psychological aspects of informative fire warning systems (No. BR127). Garston, Watford: Building Research Establishment.

Donald, I., & Canter, D. (1990). Behavioural Aspects of the King's Cross Disaster. In I. Donald (Ed.), Fires and Human Behaviour (2 ed., pp. 15-30). London: David Fulton.

Enander, A. (2005). Människors förhållningssätt till risker, olyckor och kriser. Karlstad: Räddningsverket.

Fennell, D. (1988). Investigation into the King's Cross Underground Fire. London: The Department of Transport.

Foddy, W. (1993). Constructing questions for interviews and questionnaires: theory and practice in social research. Cambridge: Cambridge University Press.

Fridolf, K., & Nilsson, D. (2010). People's Subjective Estimation of Fire Growth: An Experimental Study of Young Adults. [Not yet published]

IEC. (1995). Dependability management - Part 3: Application guide - Section 9: Risk analysis of technological systems: International Electrotechnical Comission.

Kanji, G. K. (2006). 100 Statistical tests (third ed.). London: SAGE.

Kaplan, S., & Garrick, B. J. (1981). On the quantitative definition of risk. Risk Analysis, 1(1), 11-27.

Karlsson, B., & Quintiere, J. G. (2000). Enclosure Fire Dynamics. Boca Raton: CRC Press.

Keane, J. R. (1982). Report of the Tribunal Inquiry on the Fire at the Stardust, Artane, Dublin, on the 14th February, 1981. Dublin: The Stationery Office.

Kobes, M., Helsloot, I., de Vries, B., & Post, J. G. (2010). Building safety and human behaviour in fire: A literature review. Fire Safety Journal, 45(1), 1-11.

Kuligowski, E. D. (2008). Modeling Human Behaviour during Building Fires (NIST Technical Note 1619): National Institute of Standards and Technology.

Kuligowski, E. D. (2009). The Process of Human Behaviour in Fire. Paper presented at the 4th International Symposium on Human Behaviour in Fire, Cambridge, UK.

Körner, S., & Wahlgren, L. (2006). Statistisk dataanalys. Lund: Studentlitteratur.

McConnell, N. C., Boyce, K. E., Shields, J., Galea, E. R., Day, R. C., & Hulse, L. M. (2010). The UK 9/11 evacuation study: Analysis of survivor's recognition and response phase in WTC1. Fire Safety Journal, 45(1), 21-35.

Morris, W. A. (1984). Stardust Disco Investigation - Some Observations on the Full-Scale Fire Tests. Fire Safety Journal, 7(3), 255-265.

Nilsson, J. (2003). Introduktion till riskanalysmetoder (No. 3124). Lund: Lund University.

Pigott, P. T. (1984). The Fire at the Stardust, Dublin - the Public Inquiry and Its Findings. Fire Safety Journal, 7(3), 207-212.

Proulx, G. (2001). Occupant behaviour and evacuation. Paper presented at the 9th International FIre Protection Symposium, Munich, Germany.

Proulx, G. (2008). Evacuation Time. In P. J. DiNenno (Ed.), SFPE Handbook of Fire Protection Engineering (Fourth ed.). Quincy, Massachusetts: National Fire Prtection Association.

Proulx, G., & Fahy, R. F. (1997). The Time Delay to Start Evacuation: Review of Five Case Studies. Paper presented at the 5th International Symposium on Fire Safety Science, Melbourne, Australia.

Purser, D. A., & Bensilum, M. (2001). Quantification of behaviour for engineering design standards and escape time calculations. Safety Science, 38(2), 157-182.

Rasbash, R. J., Ramachandran, G., Kandola, B., Watts, J. M., & Law, M. (2004). Evaluation of fire safety. Chichester, England: John Wiley & Sons, Ltd.

Renn, O. (1998). The role of risk perception for risk management. Reliability Engineering & System Safety, 59(1), 49-62.

Riskkollegiet. (1993). Upplevd risk. Stockholm: Riskkollegiets skriftserie.

Rundmo, T., & Moen, B. E. (2006). Risk perception and demand for risk mitigation in transport: A comparison of lay people, politicians and experts. Journal of Risk Research, 9(6), 623-640.

Sime, J. D. (1998). Visual Access Configurations: Spatial Analysis and Occupant Response Inputs to Architectural Design and Fire Engineering. Paper presented at the 15th International Association for People-Environment Studies Conference, Eindhoven.

Sime, J. D. (1999). Crowd facilities, management and communications in disasters. Facilities, 17(9/10), 313-324.

Slovic, P. (2001). The risk game (Reprinted from 'The risk game'). Journal of Hazardous Materials, 86(1-3), 17-24.

Särdqvist, S. (2006). Vatten och andra släckmedel. Karlstad: Räddningsverket.

Tong, D., & Canter, D. (1985). The Decision to Evacuate - a Study of the Motivations Which Contribute to Evacuation in the Event of Fire. Fire Safety Journal, 9(3), 257-265.

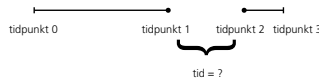Wood, P. G. (1972). *The Behaviour of People in Fires* (No. 953): Fire Research Station.

Appendix 1

Slide 1:

Examensarbete vid Avdelningen för brandteknik och riskhantering

Karl Fridolf

1

Slide 2:

Beskrivning av del 1

1. Du får se ett filmklipp på det inledande skedet av ett brandförlopp (tidpunkt 0 - tidpunkt 1 i figuren nedan).

2. Du får därefter se en filmsekvens (3 sekunder lång) av samma brandförlopp, men vid ett senare tillfälle (tidpunkt 2 - tidpunkt 3 i figuren nedan).
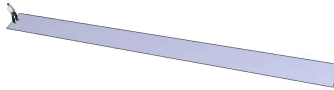
tidpunkt 0   tidpunkt 1   tidpunkt 2 tidpunkt 3

tid = ?

3. Du får uppskatta tiden mellan tidpunkt 1 och tidpunkt 2.

Lunds universitet / Lunds tekniska högskola / Avdelningen för brandteknik och riskhantering / Karl Fridolf   2

Slide 3:

Testexempel

Det här är ett exempel för att visa hur undersökningen kommer att gå till.
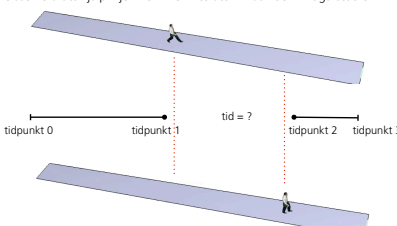
Nedan kommer en film på en person som promenerar i en korridor att visas. Titta noga på filmen!

Lunds universitet / Lunds tekniska högskola / Avdelningen för brandteknik och riskhantering / Karl Fridolf   3

Slide 4:

Överst visas den sista bildrutan i filmen som du precis såg. Nedanför bilden visas en filmsekvens från ett senare skede i filmen. Försök att uppskatta tiden mellan bilden och filmsekvensen. Skriv ner ditt svar i enkäten.
Observera att hjälplinjen kommer inte att finnas i den riktiga studien.

tidpunkt 0   tidpunkt 1   tid = ?   tidpunkt 2   tidpunkt 3

Lunds universitet / Lunds tekniska högskola / Avdelningen för brandteknik och riskhantering / Karl Fridolf   4

Slide 5:

Studien

Nu har du fått se ett exempel på hur studien kommer att gå till. Om du har några frågor ber jag dig att ställa dem nu.

Nu börjar den riktiga studien!

Lunds universitet / Lunds tekniska högskola / Avdelningen för brandteknik och riskhantering / Karl Fridolf   5
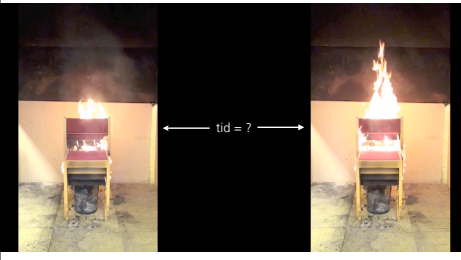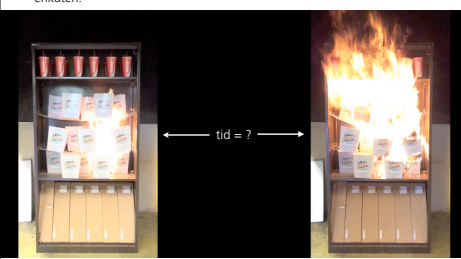
Slide 6:

Film 1

Nedan kommer en 25 sekunder lång film på en brand i en stolstapel att visas. Titta noga på filmen!

Lunds universitet / Lunds tekniska högskola / Avdelningen för brandteknik och riskhantering / Karl Fridolf   6

Till vänster visas den sista bildrutan i filmen som du precis såg. Till höger om bilden visas en filmsekvens från ett senare skede i filmen. Försök att uppskatta tiden mellan bilden och filmsekvensen. Skriv ner ditt svar i enkäten.

tid = ?

Film 2

Nedan kommer en 25 sekunder lång film på en brand i en hylla med popcorn att visas. Titta noga på filmen!

Till vänster visas den sista bildrutan i filmen som du precis såg. Till höger om bilden visas en filmsekvens från ett senare skede i filmen. Försök att uppskatta tiden mellan bilden och filmsekvensen. Skriv ner ditt svar i enkäten.

tid = ?

Beskrivning av del 2

1. Du får se ett filmklipp (3 sekunder) av en brand.

2. Du får därefter bedöma dina möjligheter att släcka branden med hjälp av en handbrandsläckare (pulversläckare, 6 kg)

Till vänster visas en upprepad filmsekvens av en brand. Tror du att du hade kunnat släcka branden till vänster med hjälp av handbrandsläckaren (6 kg pulver) till höger? Skriv ner ditt svar i enkätens andra del för Film 1!

Till vänster visas en upprepad filmsekvens av en brand. Tror du att du hade kunnat släcka branden till vänster med hjälp av handbrandsläckaren (6 kg pulver) till höger? Skriv ner ditt svar i enkätens andra del för Film 2!

40

Del 3

Slutligen vill jag be dig att svara på de sista frågorna i enkäten.

Stort tack för att du ställde upp!

Appendix 2

Svarsenkät

Denna studie syftar till att undersöka hur människor i allmänhet uppfattar och uppskattar de tidiga stadierna i ett brandförlopp. Resultaten kommer att analyseras och användas för att utveckla förståelsen för mänskligt beteende i bränder.

Enkäten består av tre delar. I den första delen ska du uppskatta tiden mellan två filmsekvenser för olika brandförlopp. I den andra delen ska du bedöma din förmåga att släcka en brand med hjälp av en handbrandsläckare för olika bränder. I den tredje och avslutande delen ska du besvara några generella frågor om kön, ålder och akademisk bakgrund. **Dina svar kommer naturligtvis att behandlas konfidentiellt, de kommer med andra ord inte att kunna spåras tillbaka till dig!**

Del 1 – Uppskattning av tiden mellan två filmklipp

Hur lång tid tror du att det har gått mellan bilden och filmsekvensen? Vänligen ange ditt svar för respektive brand nedan.

Testexempel: _____ minuter _____ sekunder

Film 1: _____ minuter _____ sekunder

Film 2: _____ minuter _____ sekunder

Del 2 – Uppskattning av förmåga att släcka en brand

Tror du att du hade kunnat släcka branden till vänster med hjälp av brandsläckaren i bilden till höger (en 6 kg pulversläckare)? Vänligen ange ditt svar genom att markera med ett kryss i rutorna nedan.

Film 1:

Ja ☐
Nej ☐
Vet ej ☐

Film 2:

Ja ☐
Nej ☐
Vet ej ☐

Del 3 – Generella frågor

Nedan följer några frågor om dig själv. Dessa frågor ställs för att jag i studien ska kunna undersöka huruvida det finns skillnader mellan olika kategorier av människor, t.ex. mellan män och kvinnor. **Dina svar behandlas naturligtvis konfidentiellt!**

1. Vilket år är du född?

19 _____

2. Markera med ett kryss vilket kön du tillhör:

Man ☐

Kvinna ☐

3. Vad har du för akademisk bakgrund (markera med ett kryss)?

Förgymnasial utbildning (examen från grundskola, folkskola, enhetsskola eller realskola) ☐

Gymnasial utbildning ☐

Eftergymnasial utbildning ☐

Forskarutbildning ☐