



UNIVERSIDADE DE LISBOA
FACULDADE DE MOTRICIDADE HUMANA



"Effect of Time Pressure in Behavioural Compliance with Warnings: A Study with Virtual Reality"

Dissertação Elaborada com vista à obtenção do Grau de Mestre em Ergonomia

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Abstract:

Warnings, posted signs, alarms and labels on products are a constant in our everyday routine. All this information is made available with the main purpose of warning us of the risks and dangers to which we are exposed. The purpose of the present study was to examine how time pressure affects the compliance with warnings/ posted signs and exit signs. A virtual reality (VR) scenario was used. Fifty participants, were divided in two groups, one with no time pressure and the other with time pressure, to perform a work security verification routine during which a fire occurred and the participants had to leave the building guided by the exit signs. The results suggests that, under time pressure, the compliance with signs is worse. This work aims to contribute to the design of more effective warnings.

Keywords: Time Pressure; Warnings; Behavioural compliance; Virtual reality; Ergonomics; CHIP Model; Signage; Exit Signs; Human Behaviour; Safety.

Resumo

Avisos, sinais, alarmes e rótulos de produtos são uma constante no nosso dia-a-dia. Esta informação é disponibilizada com o objetivo de nos alertar para os riscos e perigos a que estamos expostos. Este trabalho teve como objectivo avaliar como a pressão temporal influencia a consonância comportamental com avisos/sinais e sinalização de saída de emergência. Para tal, utilizou-se um cenário de realidade virtual (RV). Cinquenta participantes divididos em dois grupos, um sem pressão temporal e outro com a pressão temporal, tinham de executar uma rotina de verificação de segurança, durante a qual ocorria um incêndio e, para saírem do edifício, os participantes tinham de seguir os sinais de saída de emergência. Os resultados sugerem que, sob pressão temporal, a consonância comportamental com sinais é pior do que quando não existe pressão temporal. Este trabalho tem como objetivo contribuir para a concepção de avisos mais eficazes.

Palavras - chave: Pressão Temporal; Avisos; Consonância comportamental; Realidade Virtual; Ergonomia; Modelo CHIP; Sinalização; Sinais de Evacuação; Comportamento Humano; Segurança. ▸

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1. Introduction

Warnings, posted signs, alarms and labels on products are a constant in our everyday routine. All this information is made available with the main purpose to warn us of the risks and dangers to which we are exposed.

According to Wogalter (2006) the four main purposes or functions of warnings are:

First: Be a method for communicating important safety information in order to provide people adequate information about hazards so they can make informed decisions on how to avoid getting themselves or others hurt. In order to accomplish this function some salient features are incorporated in the design of warnings in a way to call attention to themselves.

Second: Warnings are intended to influence or modify people's behaviour with the intention to improve safety.

Third: Warnings are intended to reduce or prevent health problems, workplace accidents, property damage and personal injury.

Fourth: It can be a reminder for people who already know information about the hazardous.

There are many kinds of warnings. It can be in the form of audio, labels, signs, tags, etc.

In general a warning is consisted by two areas:

- A. Signal Word Panel: Has the objective of capture attention. It can have text, symbols or both and is consisted by three parts:
 - a) Signal word: Danger, Warning or Caution.
 - b) Color coding: Red for danger, orange for warning and yellow for caution

- c) An alert symbol: An exclamation point inside a triangle icon.
- B. Message Panel: Has three components that can be text, symbols or both.
The components are:
- a) Hazard information: identifies the danger (e.g., high voltage).
 - b) Instructions: tell what to do or not do to avoid the hazard (e.g., keep out).
 - c) Consequences: describe what may happen if the hazard is not avoided (e.g., death)

When information can be readily inferred from the other information presented in the warning one or more components can be eliminated.

Standardization of safety-related warning messages has the goal of making the warnings easy to recognize and easy to understand, and thus limiting the human and money cost of foreseeable errors and accidents. There are three major organizations working in this field: ANSI (the American National Standards Institute) and ISO (the International Organization for Standardization) and OSHA (the Occupational Safety & Health Administration of the U.S. Department of Labor).

In 2013: OSHA updated its rules on safety signs and tags—regulations which had not been changed since their inception in 1971. The new rule incorporates the appropriate ANSI Z535-2011 standard reference into OSHA's standards wherever safety signs, colors and tags are specified.

ISO and ANSI have similar goals – uniform systems to give users and others information about hazards, the severity of the hazards, and how to avoid them. The major difference is the method each system uses to achieve its goals. ISO places a heavier reliance on pictorial warnings than ANSI. In fact, the ISO warning can be exclusively pictorial. By contrast, the ANSI standard mandates that a

signal word and a message panel provide necessary information to the product user.

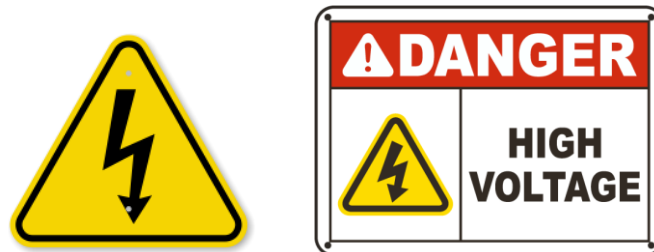


Figure 1 - ISO (left) vs OSHA/ANSI (right) warnings

Yet, despite all this information, accidents still happen, some of them, because we ignore the alerts (Paul & Stimers, 2012). We need to ensure that warnings are effective, or consider alternative ways of reducing the risks.

An important consideration in safety analysis and accident prevention is the identification of warnings and signs and how we respond to them. Knowing how people react to time pressure is very important to design safer environments.

This study builds on the work of Duarte (2010), on the use of virtual reality environments for assessing compliance with warnings. After Duarte's (2010) work, the importance of studying whether time pressure affects the compliance with warnings was identified.

Managers and other professional decision makers frequently identify time pressure as a major constraint on their behaviour (Svenson & Maule, 1993).

Although behavioural compliance is the gold measure, it is very difficult to assess and Virtual Reality (VR) has proven to be a reliable and useful tool to identify behavioural compliance (Duarte, Rebelo & Wogalter, 2010).

Prior studies used VR to evaluate which environmental features have influence on route selection in an emergency situation (Vilar, Rebelo, Noriega, Teles & Mayhor, 2013) and how that environmental variables, when used with signage, influences on route choices in everyday and emergency situations (Vilar, Rebelo, Noriega, Duarte & Mayhorn, 2014).

Once the scenario used in Duarte's (2010) study, for evaluating behavioural compliance with warnings, has proved to be suitable, it was determined that in this study the same scenarios would be used, with only small changes, either in the experimental and pre-experimental training with virtual reality. As Duarte's (2010) conclude in her work the compliance with dynamics signs is higher than the compliance with static signs and for this reason it was decided to use dynamics signs in an uncluttered environment (DUC) for this study.

1.1 Question in Study

Does time pressure affects behavioural compliance with warnings?

2. Literature Review

2.1 Warnings

Since the mid-1980s there has been a significant increase in research on safety communications, more specifically, warnings. Research was conducted by researchers from different fields, but a substantial portion of the research has been carried out by ergonomists (Laughery, 2006). That isn't surprising because warnings are part of the interface for people using and maintaining a product or environment and such interfaces are in the domain of ergonomics.

Warnings can be defined as an advance notice of something. In safety, warnings are used as messages to inform people about hazards, and its objective is to prevent accidents, health problems, injury or damages. Understanding the best way to present warning information is a complex undertaking.

Through time there has been a large number of research studies which have helped to produce reasonable consensus in identifying the design principles for good warning signs (e.g., Wogalter, Conzola, & Smith-Jackson, 2002; Adams, Bochner & Bilik, 1998; Laughery, 2006) but, despite this work, some of the literature and empirical knowledge indicates that even well-designed signs are not totally effective. On his investigation DeJoy (1989) found warning compliance rates ranging from 17% to 37%. Even an apparently well-designed sign doesn't raise compliance to 100%.

Nowadays, with all the technology we have at our disposal, we are able to develop more efficient warnings, making it possible to replace traditional visual signs or product labels for dynamic, audio and tactile ones to enhance risks communication (Wogalter & Mayhorn, 2005; Haas & Erp, 2014)

2.1.1. Warnings Vs Posted Signs

As this study is based on Duarte's work (2010) we used the same classification to distinguish the different signs used in the virtual environment. The classification is present below:

"Warnings: Warnings, which were placed in the room area, contained explicit safety messages that provided information about a hazard and its consequences, as well as guidance on how to avoid the hazard. Warnings were the main target of the behavioural compliance evaluation. Both warnings and the scenario where they were embedded, were designed in a way that the participants could not expect them, as they were not pre-cued ahead of time by the task instructions that the participants carried out. Nevertheless they were placed coherently within the VR scenario.

Posted signs: The second type of safety information was posted signs. These posted signs had a different role than the warnings. They identified a safety device (e.g., a gas valve) and their contents were mentioned within the instructions given to participants on the tasks they were to perform, thus, the contents were pre-cued or expected prior to them being viewed in the VE. As a result, we expected to attain high values of compliance in such cases.

Finally, the exit signs were used to mark the routes of egress."

(Duarte, 2010, p. 82)

2.2 Human process information

Understanding how people access, evaluate and process information is essential to do this research. There are many different theoretical approaches of risk perception, grounded in different bases (Riley, 2014):

- a) **Value- expectancy theory:** Founded by Martin Fishbein in the 1970s, this theory states that behaviour is a function of the interaction between a person's expectancies about the outcome of actions and the value they place on them (Wigfield, 1994).

- b) **Social learning theory:** Developed by Bandura (1971) this theory states that people learn from one another, via observation, imitation and modelling.

- c) **Protection motivation theory:** Developed by Rogers in 1975 this theory proposes that we protect ourselves based on four factors: the perceived severity of a threatening event, the perceived probability and vulnerability of the occurrence, the efficiency of the recommended preventive behaviour, and the perceived self-efficiency (Floyd & Rogers, 2000).

- d) **Mental Models Methodology:** This methodology was developed with the aim of understanding what judgment and decision processes people use to respond to a hazard (Bostrom, Fischhoff & Morgan, 1992).

- e) **Communication- Human Information Processing (C-HIP) Model:** This model describes the route from attending to a warning and comply with it by assuming a certain behaviour. Derived from information-processing theories, the C-HIP model suggests that the receiver moves through several stages before adhering to the warning (Wogalter, Dejoy, & Laughery, 1999).

Several models have been proposed to help to understand which factors contribute to warning effectiveness (Conzola & Wogalter, 2001; Wogalter,

Conzola & Smith-Jackson, 2002) and two topics are common to the most of them - attention and behavior.

2.2.1 Communication- Human Information Processing (C-HIP) Model

The C-HIP model has been frequently used by researchers as a research framework about warnings (Conzola & Wogalter, 2001; Visscherst, Rutter, Kools, & Meertenst, 2004) This model helps to identify where, in the stages of processing, failure occurs, enabling the warning designer to focus on alternative designs that increase the likelihood of success.

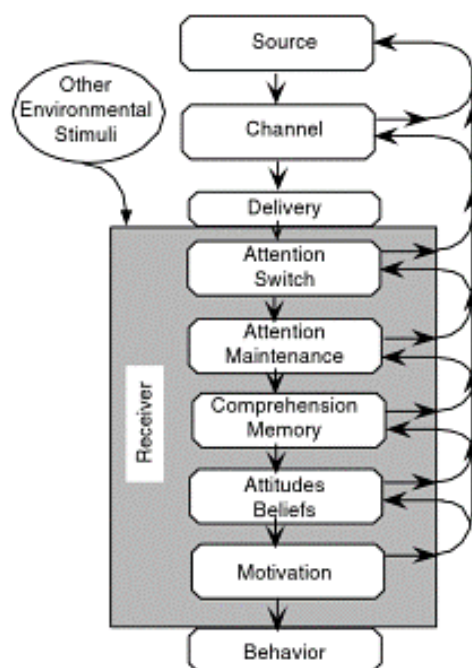


Figure 2 - The C- HIP model (Karwowski, 2006)

The C-HIP model begins with a source delivering a warning to a receiver, through a channel, along with other environmental stimuli that may distract him from the message. The receiver goes through five information processing steps which, ultimately, determine whether the warning results in any change in behaviour.

The feedback loops shown on the right side of Figure 2 indicate that what happens at one stage can influence other stages. Thus, the processing of a warning message may be more complex than a simple flow of information through a linear sequence of stages (Laughery, 2006).

Next, each of the stages of the C–HIP model will be described.

The Source:

It is the originator or initial transmitter of the risk information. It can be a person or an entity (e.g., the government). Before the source actually transmits a warning there must be a recognized need for the warning.

The Channel

It concerns the way information is transmitted from the source to one or more receivers. There are two dimensions of the channel, one concerns the media in which the information is embedded and the other to the sensory modality used by the receiver to capture the information.

The Receiver

The mental activities can be categorized into a sequence of information processing stages. In their article, Conzola and Wogalter (2001), explains that for a warning to effectively communicate information and influence behaviour, it must first cause attention to be switched to it and maintained long enough for the receiver to extract the necessary information from the warning. Next, the warning must be understood, and must concur with the receiver's existing attitudes and beliefs. If it is in disagreement, the warning must be adequately persuasive to evoke an attitude change toward agreement. Finally, the warning should motivate the receiver to perform proper compliance behaviour. The stages of information processing that occur within the receiver will be described below:

- a) **Attention switch:** An effective warning must initially attract attention. Generally this must occur in environments which also have other stimuli competing for attention. Since many industrial environments are cluttered, visual warnings must stand out from the background in order to be noticed.
- b) **Attention maintenance:** Individuals might notice the presence of a warning but not stop to examine it. A warning that is noticed but fails to maintain attention long enough for its content to be encoded is of little value.
- c) **Comprehension Memory:** The message has to be well understood by the receiver. A warning message should give the receiver an appreciation of risks and enable informed judgment.
- d) **Beliefs and attitudes:** Beliefs are the individual's knowledge of a topic that are accepted as true. Attitudes are similar to beliefs but have greater emotional involvement.
- e) **Motivation:** the motivation needed to do the desired behaviour. An important factor influencing motivation is the balance between the cost of complying with a warning and the cost of noncompliance.
- f) **Behaviour:** Is the result of the mental activities of information processing stages. What we can see.

2.3 Compliance

Montgomery (2015), defines compliance as "(...) the performance of an action, or the termination of an action, at to a request."

Warnings are developed with the aim of persuade people to do something in order to protect them from hazard, for example. We can see behaviour but we cannot see compliance, we assumed that if the behaviour is corrected there was compliance. But we need to know which factors affect compliance in order to developed better warnings.

2.4 Time Pressure

Time pressure can be defined as the difference between the amount of available time and the amount of time required to solve a task. (Rastegary & Landy, 1993)

There isn't a consensus about how time pressure affects performance.

Research on how time pressure affects performance has demonstrated clearly that time pressure increases the rate of individual and group performance (Karau & Kelly, 1992). However, results have been much less consistent on the quality of performance, with evidence of a positive relationship (Goodie & Crooks, 2004) a negative relationship (Moore & Tenney, 2012), a curvilinear relationship indicating an optimal level of moderate time pressure (Isenberg, 1981), and no relationship at all (Goodie & Crooks, 2004).

Recently there has been an increase in the number of studies on how time pressure affects decision making. Most of the studies conclude that under time pressure it is more likely that a poor decision is made (Hu, Wang, Pang, Xu, & Guo, 2015; Zakay & Wooler, 1984) Time pressure, also, promotes more risk seeking than under no time pressure (Hu, Wang, Pang, Xu & Guo, 2015; Madana, Spetch & Ludvig)

2.5. Hypothesis

According with the previous findings reported in the literature the following hypothesis were defined:

H1: In time pressure situations people have worse behavioural compliance than in a no time pressure situation.

H2: With time pressure subjects should take less time to complete tasks

3. Method

3.1. Experimental Design

The chosen methodology was a comparative study.

It was set out to compare the compliance of individuals when carrying out a work security verification routine in which, for the successful accomplishment of the intended task, some instructions and warnings should be taken in attention. At a given moment of the task, a fire started (hazardous situation) and participants had to leave the building as soon as possible. To leave the building they had to rely on exit signs located in the environment.

The "time pressure" group had as main goal to accomplish the task in 4mins and 30 seconds. They were being informed on how much time they had every 5 seconds with an audio message. This audio message was previously recorded and inserted in the Virtual Environment (VE).

3.2. The session

After the participants had finished the training session, they took part in one of the two experimental conditions. Before starting the interaction with the virtual simulation, one cover story (Appendix I and Appendix II), depending on the experimental condition, was told with the purpose of introducing the task and the scenario to them.

In the VR simulation, the participants had to fulfill several tasks inside the VE, involving entering each one of the main four rooms in the following order: Meeting room, Laboratory, Food Processing Zone and Warehouse. In the VE, several warnings and posted signs were placed on the walls of the rooms. To facilitate the tasks, written instructions concerning safety warnings were left in each room, indicating what should be done.

The sequence of tasks was the one below:

1. The participants were told they should start the procedure by getting to the Meeting Room.
2. Inside the Meeting Room, the following instructions were displayed: "Check for Walkie-Talkies on top of the tables. If any is there take it with you. If not, please go to the laboratory and activate de security system."
3. Switch on de fire detector near the exit door.
4. Do not activate the button at the entrance of the laboratory.
5. Inside the Laboratory, Sign 5 was present – "Security system".
6. The instruction displayed inside this room was: "Now, go to the Food Processing Zone and switch the gas off".
7. Outside the Food Processing Zone, close to the entrance door was Warning 3, which stated "Disinfection system, mandatory to warn before entering".
8. Inside the Food Processing Zone, Sign 6 – "Shut-off gas" was present together with a button switch.
9. The instruction given was "After the gas is shut-off, go to the Warehouse and cut the energy to the machine room".
10. Outside the Warehouse, whose door was closed, was Warning 4, which stated: "Polluted atmosphere, start extractor before entering the room". There was only one way to open the door, which was by pressing the button adjacent to the warning 4.
11. Inside the Warehouse was a button switch adjacent to Sign 7, which stated: "Cut energy to machine room". Since this was the last room, no further instructions were given here.
12. After entering the warehouse, or 4:30 minutes after entering the corridors leading to the warehouse, a fire started in the Warehouse.

The entire experiment and the content of the warnings and posted signs, as well as all the experimental instructions (print and oral) were communicated in Portuguese.

3.3 Variables

The only variable manipulated was "time pressure" with two levels: high and low.

The dependent variables were behavioural compliance and task time.

3.4. Participants

Fifty participants were recruited, 21 female and 29 male, aged 18 to 30 years old.

The average age of all participants was 22 years old (SD= 3.28 years).

Participants were unpaid volunteers and were recruited from the FMH campus.

They were randomly divided into two groups - 27 performed the procedure with time pressure condition and 23 without time pressure condition.

3.5. Materials

3.5.1. Questionnaire

The questionnaire was applied at the end of the experiment with the objective of collecting demographic data, games and VR level of expertise, evaluate sensorial experience and the perception of hazard by each participant.

3.5.2. ErgoVR

ErgoVR is a Virtual Reality System developed at the Ergonomics Laboratory of FMH which allows the collection, visualization, measurement and analysis of data regarding human behaviour variables during the interaction with virtual environments, to be used mainly in Ergonomics for Design studies.

ErgoVR automatically collects behavioural interaction variables - trajectories, collisions, dislocation paths, etc (Teixeira, Rebelo & Filgueiras, 2010).

3.6 Equipment

In this research the following gear was used:

- a) One desktop PC equipped with an Intel Quad-Core processor, 8 GB of RAM and a NVIDIA graphics card
- b) Monitor HP (model L 1702)
- c) A joystick from Thrustmaster
- d) Wireless stereo headphones from Sony®, model MDR-RF800RK
- e) A Targa DVD, model DRH-5000
- f) An HMD from Sony® PLM-S700E
- g) An AEE® wireless infrared video camera, model AT207
- h) Two magnetic motion trackers from Ascension-Tech®, model Flock of Birds

3.7. Experiment Facilities

The study took place in the VR Unit of Ergonomics laboratory of the Faculty of Human Kinetics of Universidade de Lisboa. The area of the VR Unit was divided in two interconnected rooms, one used to introduce the study and complete the questionnaires (Room 1) and the other used for the VR equipment, where the participant interacted with the VE (Room 2). Room 2 remained with the door closed and the lights off during the entire interaction.

3.8. Virtual Environment

The virtual environment used was the same described by Duarte (2010) in her work but with some differences. Different warnings/posted signs, instead of

having a cafeteria there was a food processing zone and there wasn't an explosion before the fire starting.

Like in Duarte's study (2010) the VE layout (see Appendix III) were divided in to big areas: the room area and the escape area.

The room area, was constituted by 4 rooms: a) meeting room; b) laboratory; c) food zone processing zone and d) warehouse. Each room had 12x12 meters size. To interconnect the rooms there were 2 symmetrical and perpendicular axes corridors, 2 meters wide. Another corridor circumvent the rooms and leaded to the escape routes area.

The escape routes area consist of a sequence of six corridors in a t-shaped format, in which only one of the options (right/left) provides access to the exit.

The triggers that activate the fire were positioned inside the warehouse and in surroundings.

The instructions given to the participants (see topic 3.10, page 31) assure, when correctly followed, the following rooms route:

- 1 – Meeting room;
- 2 – Laboratory;
- 3 – Food processing zone;
- 4 – Warehouse.



Figure 3 – Starting Point



Figure 4- Meeting room



Figure 5- Laboratory



Figure 6 - Fire at warehouse

3.9. Warnings, posted signs and exit signs used:

The warnings used in this study are presented below.



Figure 7- Warnings used in Virtual Environment

The posted signs used were the following ones.



Figure 8- Posted Sign used in virtual environment

The exit signs used were this:



Figure 9- Exit sign used in virtual environment

3.9.1. Ambiguous sign

In the real world nothing is linear and sometimes we face situations different from ours expectations and have to make decisions to solve the problem in hand. For this reason, in our study, we decided to place an ambiguous sign.

The sign, named “process control “had an “Out of order” label which configures a potentially ambiguous situation in reference to what is considered as compliance.

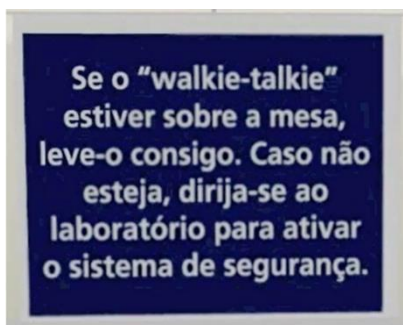


Figure 10- Ambiguous sign

This sign wasn't taken into consideration for the results but prior research reported that ambiguous warning messages have worse compliance than non-ambiguous warnings (Duarte, Rebelo, Teles & Noriega, 2012).

3.10. Instructions presented in VE

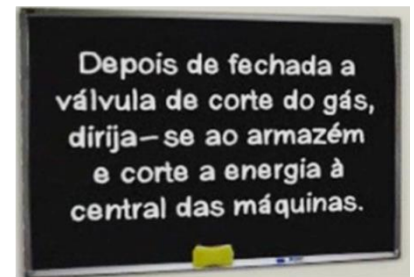
During the task the following instructions were presented.



"Check for Walkie-talks on the top of the tables if any is there take it with you. If not, please go to the laboratory and activate the security system."



"Now, go to the Food Processing Zone and switch the gas off".



"After the gas is shut-off, go to the Warehouse and cut the energy to the machine room".

Figure 11- Instructions

3.11. Procedure

The procedure was divided in three parts:

- 1) Training session
- 2) Experimental session
- 3) Questionnaire answering

Prior to the beginning of the training session, a brief explanation about the study was given to the participants whom, after this, were asked to read and sign an

informed consent form. After the training session the narrative was presented and the experimental session began. When the experiment was finished the questionnaire was presented for answering.

If after 4:30 min the participant steel in the room area, the audio message stopand the fire start at the corridor.

The complete procedure took 40 minutes to complete.

4. Results

The compliance assessment was accomplished in two separate, but subsequent, stages of the simulation – prior to the fire and following the fire.

4.1. Behavioural compliance

The first stage, which was intended to evaluate compliance with warnings/posted signs, took place when participants were requested to perform the routine security check. The data collected during this phase was collected by ErgoVR and presented in the following scores: (100% success = 3 pressed buttons).

4.1.2 Global compliance

Global compliance: is computed by combining the two compliance scores (“With Pressure” and “No Pressure”). It was measured by the number of times the participants pressed the buttons, as directed by the warnings and posted signs present in the rooms area of the VE (100% success = 6 pressed buttons).

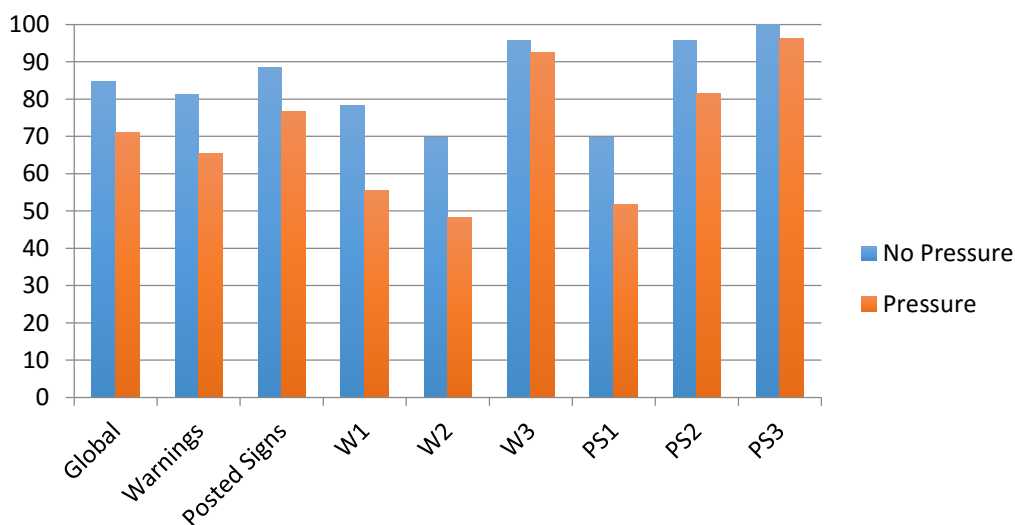


Chart 1- Behavioural compliance for warnings and posted signs

As can be observed in

Chart 1 global compliance was higher in the “no Pressure Time Group” reaching 84.78% against 70.98% reached by “Pressure time“group.

To evaluate if there was a significant difference between compliance, the Mann-Whitney U test - a non-parametric test for independent samples - was applied.

Chart 1 presents the p-values. The black values are the significant ones. The p value for global compliance was 0.031 wich means there is a significant diference between the two experimental conditions. The p-value for warnings almost achieves significant diference - 0.058. The p value for Posted signs was 0.101 wich means there is no significant difference.

<i>Mann-Whitney U</i>	<i>Global</i>	<i>Warnings</i>	<i>Posted</i>
<i>z</i>	-2.153	-1.894	-1.639
<i>p</i>	0.031	0.058	0.101

Table 1- Mann Whitney U results for warnings and posted signs

A X² was applied to evaluate if there is a significant effect between each posted signs and warnings. Individually considered, there was no significative difference in any one of them (p>0.05).

<i>Chi-Square</i>	<i>W1</i>	<i>W2</i>	<i>W3</i>	<i>PS1</i>	<i>PS2</i>	<i>PS3</i>
<i>χ²</i>	2.853	2.339	0.206	1.624	2.362	0.869
<i>p</i>	0.091	0.126	0.65	0.203	0.124	0.351

Table 2- Chi-Square results for warnings and posted signs

4.1.3 Compliance with warnings

Compliance with warnings: Is indicated by the number of times the participants pressed the buttons as directed by the three warnings presented (Fire detector; disinfection system; air extractor) in the simulation (100% success = 3 pressed buttons);

As can be observed in Chart 1 compliance with warnings was higher in the “no Pressure Time Group” reaching 81.15% against 64.43% reached by the “Pressure time “group.

About compliance with warnings, presented in the Table 3 we can observe that in the two first warnings, the percentage of compliance is much lower in pressure condition. Only in the third warning the percentages are very close (92.6% for pressure and 95.6% for no pressure) the reasons why this happen will be discussed in the next chapter.

	Pressure	No Pressure
	%	%
Warnings		
<i>Fire detector (W1)</i>	55.56	78.26
<i>Desinfection system (W2)</i>	48.15	69.57
<i>Air extractor (W3)</i>	92.59	95.65

Table 3- Pressed Buttons by experimental conditions for warnings (%)

4.1.2 Compliance with Posted signs

Compliance with posted signs: is the number of times the participants pressed the buttons (security system; gas; energy), as directed by the three posted signs presented in the simulation (100% success = 3 pressed buttons);

As can be observed in Chart 1 compliance with posted signs was higher in the "No Pressure" group reaching 88.40% against 76.54% reached by "Pressure time" group.

About compliance with posted signs, presented in the Table 4 we can observe that in the first posted sign (Security system), the percentage of compliance is lower in both conditions and in "pressure Time" it is only 51.85%. The last Posted Sign - Energy off button - the compliance is very high with 96.30% for "pressure time" condition and 100% "no pressure time".

<i>Posted signs</i>	Pressure	No Pressure
	%	%
<i>Security System (P1)</i>	51.85	69.57
<i>Gas Valve (P2)</i>	81.48	95.65
<i>Energy (P3)</i>	96.30	100.00

Table 4- Pressed Buttons by experimental conditions for posted signs (%)

4.1.2 Compliance with Exit Signs

The second stage, intended to evaluate compliance with exit signs, was made after the hazardous situation happened and was collected by the researcher, who watched the route choice decisions, through the observation of the recorded videos and are present in the following score.

Compliance with exit signs: Is the number of correct turns made after seeing the exit signal. This could be an indicator that the exit signs are being detected, recognized, and understood by participants.

As can be observed in Chart 2 global compliance with exit signs was slight higher in the "no pressure time" conditional (100%) then in the "pressure time" condition (95.55%).

To evaluate if there is a significant difference between compliance the Mann-Whitney U test was again applied. Table 5 presents the p-values. The p value for global exit compliance was 0.187 wich means there is no significant diference

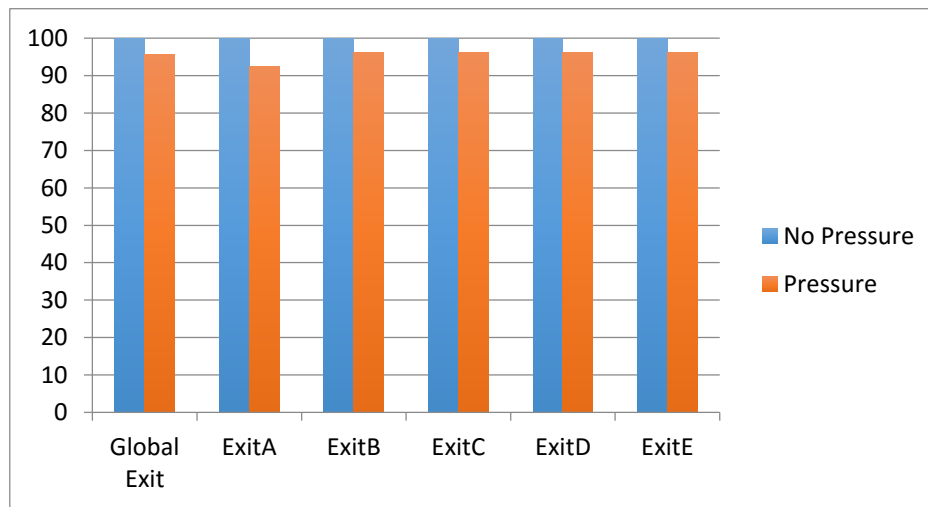


Chart 2- Compliance for Exit Signs

<i>Mann-Whitney U</i>	
<i>z</i>	-1.319
<i>p</i>	0.187

Table 5- Mann Whitney U for compliance with exit signs

A X^2 was applied to evaluate if there is significant effect between in each posted signs and warnings. Individually considered, there was no significative difference in any one of them ($p > 0.05$).

<i>Chi-Square</i>	<i>Exit A</i>	<i>Exit B</i>	<i>Exit C</i>	<i>Exit D</i>	<i>Exit E</i>
χ^2	1.775	0.869	0.869	0.869	0.869
<i>p</i>	0.183	0.351	0.351	0.351	0.351

Table 6- Chi-Square results for exit signs

4.2. Time

4.2.1 Time Spent

Task time "encompasses the period of time between the participants' first displacement in the VE to the end of the simulation. The simulation ended when a participant reached the exit/end point or when it was aborted by the researcher (around 20 minutes after the beginning without getting close to the exit point); the total time of participants took to accomplish the task was also evaluated." (Duarte, 2010, p. 132)

Average time for all participants was 355.88 seconds.

The mean time for the "Time Pressure" group was 365.28 seconds and for the "No Pressure" group was 344.85 seconds. A t-test for independent samples was made and no statistically significant difference was observed ($t=0.755$; $p>0.1$). The observation of chart 3, confirms that there is no difference between times for two groups, however the variability of the time results for the time pressure group is higher.

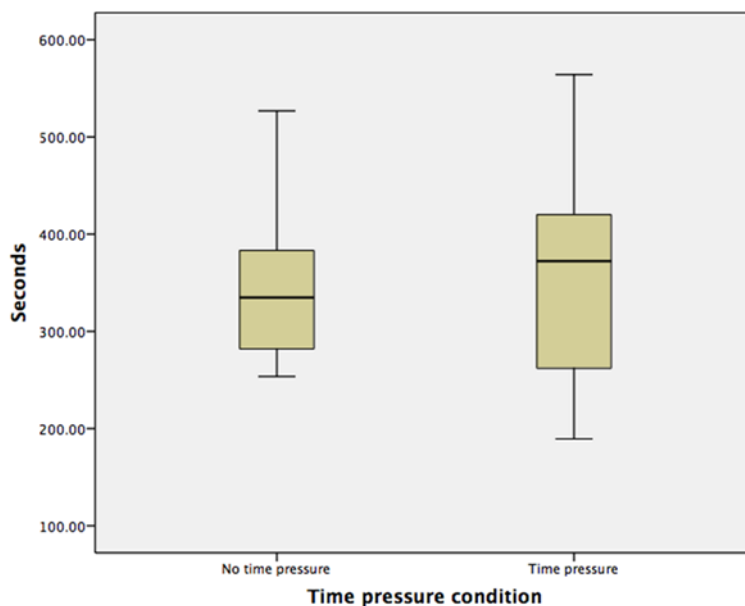


Chart 3- Boxplot for time spent

In Table 7 we can observe that minimum time to accomplish the task was achieved in “Pressure” condition (108.41 s) against 253.56s.

	<i>Pressure</i>	<i>No pressure</i>
<i>Max</i>	564.10	526.84
<i>Min</i>	189.41	253.56
<i>SD</i>	108.99	71.05
<i>Mean</i>	365.28	344.85
<i>Median</i>	372.21	334.84

Table 7- Summary statistics of the time spent in the simulation (in seconds) by condition

4.2.2. Task time

Task time is the time spent in the rooms area.

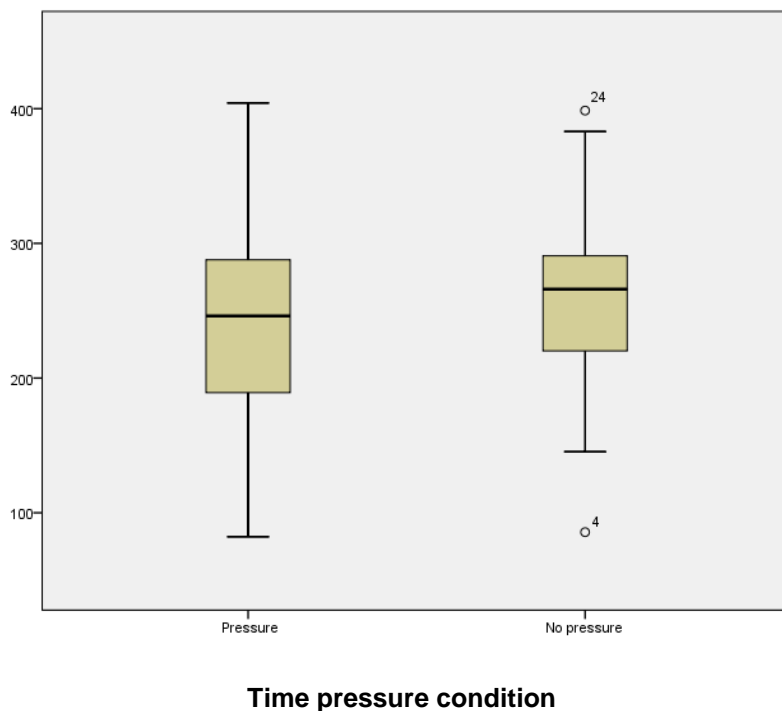


Chart 4- Boxplot time for task time

The mean time for the “Time Pressure” group was 243.43 seconds and for the “No Pressure” group was 249.20 seconds. A t-test for independent samples was made and no statistically significant difference was observed ($t= 0.267$; $p>0.1$). The observation of chart 4, confirms that there is no difference between times for two groups, however the variability of the time results for the time pressure group is higher.

In Table 8 we can observe that minimum time to accomplish the task was achieved in “Pressure” condition (82.21s) against 85.5s.

	<i>Pressure</i>	<i>No pressure</i>
<i>Max</i>	404,16	383,04
<i>Min</i>	82,21	85,58
<i>SD</i>	83,08	64,71
<i>Mean</i>	243,43	249,21
<i>Median</i>	246,11	263,01

Table 8- Summary statistics of the task time (in seconds) by condition

4.2.3. Egress time

Egress time is the time elapsed after entering in the escape routes area, encompasses the period of time the participants spent in the escape routes area.

The mean time for the "Time Pressure" group was 38.24 seconds and for the "No Pressure" group was 37.75 seconds. A t-test for independent samples was made and no statistically significant difference was observed ($t= 0.08$; $p>0.1$). The observation of chart 5, confirms that there is no difference between times for two groups, however the variability of the time results for the time pressure group is higher.

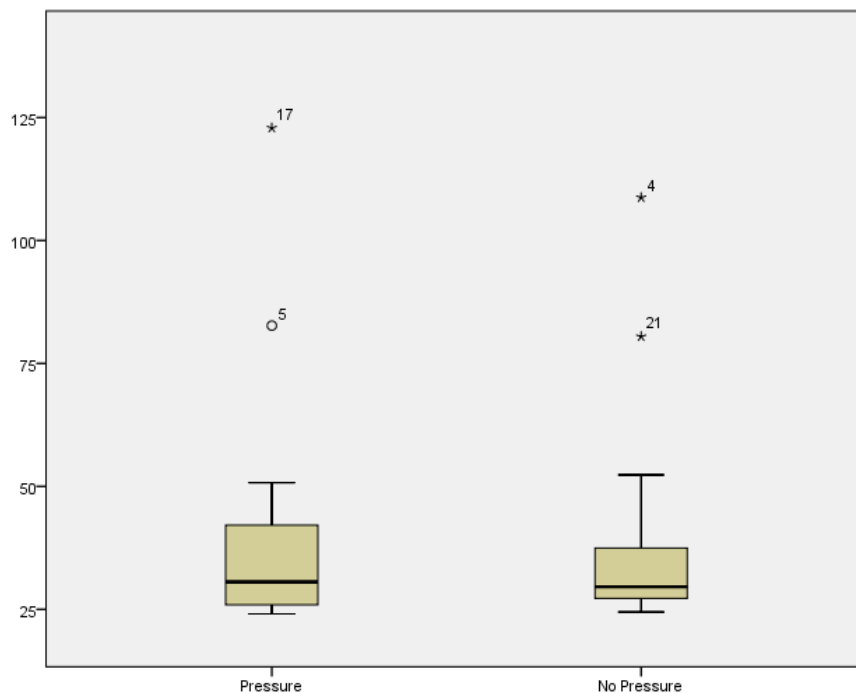


Chart 5- Boxplot time for task time

In Table 9 we can observe that minimum time to accomplish the task was achieved in "Pressure" condition (82.21s) against 85.58s.

	<i>Pressure</i>	<i>No pressure</i>
<i>Max</i>	122,90	108,73
<i>Min</i>	24,09	24,46
<i>SD</i>	21,27	19,57
<i>Mean</i>	38,24	37,75
<i>Median</i>	30,58	29,58

Table 9- Summary statistics of the egress time (in seconds) by condition

5. Discussion

The results confirmed hypothesis H1. H2 hypothesis is refuted by the results as participants with no pressure had a mean time lower than participants with pressure time. Time pressure affects negatively the compliance with warnings-. In general in a "no pressure" condition the participants had a better compliance with de warnings/posted sign.

Differences in compliance by experimental condition

In Table 1 it is observable that only global compliance presented statistical significative difference between time pressure condition and no time pressure conditions ($z=-2.153$; $p<0.05$).

As expected, the global condition was higher in the "no pressure" condition than in the "pressure condition".

Differences in compliance with warnings, by experimental condition

In warnings compliance, the observable difference is almost significative ($p=0.058$). Maybe with a higher sample we could achieve a significant difference. Also, as the third warning - "Air Extractor" - by its nature, has a very high probability of compliance, whatever the experimental condition it is presented in. It is possible that a dilution of the differences in warning compliance could be obtained by measuring the three warnings.

Differences in compliance with posted signs, by experimental condition

In

Chart 1 it is observable that in both experimental conditions the compliance with posted signs is higher than with warnings. This was expecktable accordind to Duarte's results (Duarte, 2010) that show that in an unclutered environment dynamic posted signs have higher compliance than warnings The author concludes that warnings are more effective in a clutered environment.

Differences in compliance with exit signs, by experimental condition

The compliance with exit signs had almost the same level of compliance between the experimental conditions, as we can observe in Chart 2. In the "no pressure time" condition the compliance was always 100% and in the "pressure time" condition the lowest compliance was 92.59%. These high values probably could indicate that people in an emergency situation expect to see these signs.

Differences in time spent with warnings, by experimental condition

Participants with no pressure had a mean time lower than participants with pressure time.

The mean time for the "Time Pressure" group was 365.28 seconds, for "no Pressure" group was 344.85s and for all the participants was 355.88s. Comparing the mean for all participants with the values of (Duarte, 2010) which for DUC conditions was 458.4, it is observed that, even on a pressure time condition, the mean time to accomplish the task was lower.

The minimum time achieved in the "pressure condition", 189.41s, is much higher than the one achieved in Duarte's work (2010) (48.6s), but the maximum, 564.10s, achieved in the "pressure condition" was lower than the one found in Duarte's study (2010) (804.4s).

Differences in task time with warnings, by experimental condition

Participants with pressure had a mean time lower than participants with no pressure time.

The mean time for the "Time Pressure" group was 243.43s seconds, for "no Pressure" group was 249.21s.

The minimum time achieved in the "pressure condition", 82.21s, is much lower than the one achieved in Duarte's work (2010) (152.63s), but the maximum, 404.16, achieved in the "pressure condition" was lower than the one found in Duarte's study (2010) (630.58s).

Differences in egress time with warnings, by experimental condition

Participants with no pressure had a mean time lower than participants with pressure time.

The mean time for the "Time Pressure" group was 38.24s seconds, for "no Pressure" group was 37.75s.

The minimum time achieved in the "no pressure condition", 24.46s, is much lower than the one achieved in Duarte's work (2010) (43.99s), and the maximum, 122.90, achieved in the "pressure condition" was lower than the one found in Duarte's study (2010) (319.74s).

Comparing the results obtained in this work with the results of Duarte's work (2010) it is observed that the no pressure group has the same behaviour as the dynamic uncluttered used by Duarte and the pressure time group as a similar behaviour to the dynamic cluttered.

6. Conclusion

In the future it would be interesting to study if VR is a good help to test hazard perception.

Historically, VR technology has been expensive, available to few and mostly sought out by researchers and gaming technicians (Tomasz Mazuryk, 1996). The current state of VR as a tool for many different fields like pain management, (Li, Montaña, Chen, & Gold, 2011) and for the treatment of anxiety disorders (Gershon J, 2004), for example, proved VR is valuable because it allows to study situations that in real world can't be studied due to ethical conditions.

New, cheaper and better gears are being developed, which can increase the immersivity in VE (Samsung, 2015) but also raises new questions in how these improvements affect human health and interaction.

The results of this study are important because they allow us to show that, in a time pressure situation, even well designed warnings/posted signs have a decreased compliance. Time pressure situations occur in everyday life - in work for example - and not only in emergency situations.

Other important result was in a time pressure situation the advantage of using technology is lost. This must be taken in consideration for the design of new enhanced warnings.

As a future research, it can be assessed whether the training in virtual reality, increases compliance with warnings.

In future it may interesting study the influence of workload and anxiety in behavioural compliance with warnings and how time pressure affects the compliance with warnings in cluttered and uncluttered environments.

With this work, another important step was given on studying the use of VR applications in emergency situations, being developed at the Ergonomics Laboratory of FMH.

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Appendices

Cover Story: "No Time Pressure "Group

Are you ready to begin the simulation?

For your safety, I will be always present in the room, near you. No conversation between us can happen, thus, even if you talk with me I will not answer your questions. However, if you want to quit the simulation at any moment you just need to say so and I will stop the procedure.

Please imagine the following situation:

You work as a security officer since one week ago at the "Company X" and you are in a trial period. Your supervisor requested you to replace a co-worker who had fallen sick. Thus, today, you are in a section of the building that is new to you, and which is composed by a number of rooms. Your supervisor will evaluate your work at the final of the trial period. According to the evaluation, you will continue working or your contract finishes.

We are at the end of the afternoon, the building is empty, and your task is to perform an end-of-day routine security check before closing down the work place for the night period.

To help you, your colleague left some written instructions, present in every room, posted on boards that will guide you and let you know the specific goals you are supposed to accomplish during the task. You need to understand the instructions because they will indicate you what to do and not to do.

To start the task you should go directly to the meeting room.

Can you, please, repeat which is your task and which is your first action?

Do you realize what you are supposed to do?

Are you ready to start?

Appendix I - Cover story, translated in English, for "No Time Pressure" group

Cover Story: "Time Pressure "Group

Are you ready to begin the simulation?

For your safety, I will be always present in the room, near you. No conversation between us can happen, thus, even if you talk with me I will not answer your questions. However, if you want to quit the simulation at any moment you just need to say so and I will stop the procedure.

Please imagine the following situation:

You work as a security officer since one week ago at the "Company X" and you are in a trial period. Your supervisor requested you to replace a co-worker who had fallen sick. Thus, today, you are in a section of the building that is new to you, and which is composed by a number of rooms. Your supervisor will evaluate your work at the final of the trial period. According to the evaluation, you will continue working or your contract finishes.

We are at the end of the afternoon, the building is empty, and your task is to perform an end-of-day routine security check before closing down the work place for the night period.

You have very limited time to do the routine security check.

In order to be able to keep your job, you have to accomplish the task in less time than other employees.

A beep will be heard every 30 seconds to inform you of the time.

To help you, your colleague left some written instructions, present in every room, posted on boards that will guide you and let you know the specific goals you are supposed to accomplish during the task. You need to understand the instructions because they will indicate you what to do and not to do.

To start the task you should go directly to the meeting room.

Can you, please, repeat which is your task and which is your first action?

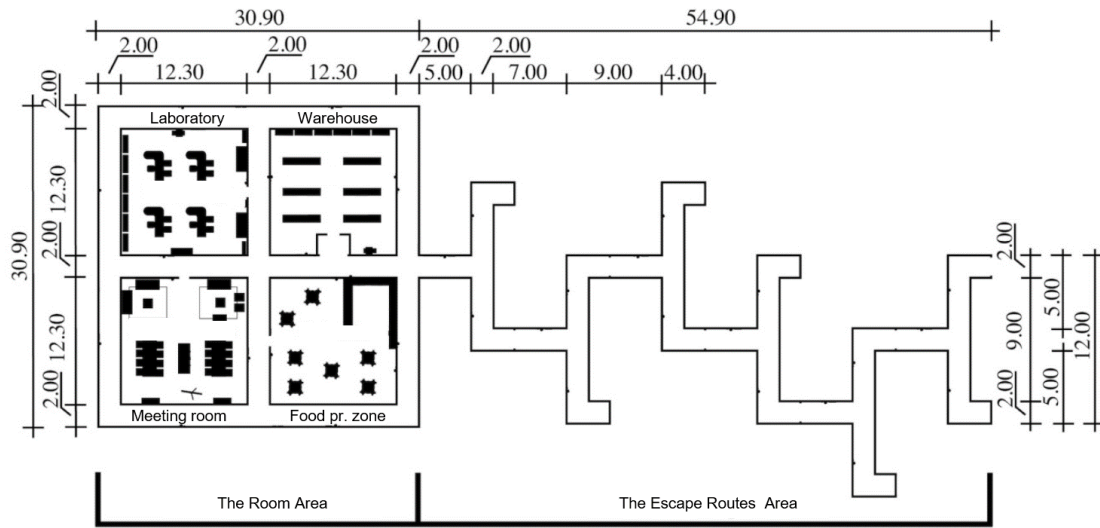
Do you realize what you are supposed to do?

Remember, the time is very important for your success.

Are you ready to start?

Appendix II - Cover story, translated in English, for "Time Pressure" group

The VE Layout



Appendix III - The VE layout