Safety @ Work:
Research Methodology

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Safety @ Work (in Dutch Veiligheid op de Werkvloer) is an initiative of the Saxion Research Centre Design & Technology. The project focuses on how to achieve safety in working environments by using ambient technology. These include personal safety, a safe environment and safe behaviour. The project started on 1 January 2011 and will run for four years. The consortium members are Saxion, University of Twente, Novay, Thales Netherlands, Norma MPM, PANalytical, TenCate Protective Fabrics, Alten PTS and Noldus Information Technology. In addition, there is a changing group of participating companies which occasionally participate in the program team. The project is funded by the Stichting Kennis Ontwikkeling HBO (SKO) under registration RAAK PRO–2–013.

Safety @ Work:
Research Methodology
Summary

In this document, we provide the methodological background for the Safety at Work project. This document combines several project deliverables as defined in the overall project plan: validation techniques and methods (D5.1.1), performance indicators for safety at work (D5.1.2), personal protection equipment methods (D2.1.2), situational awareness methods (D3.1.2), and persuasive technology methods (D4.1.2).
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1. Introduction

Ynze van Houten

The Research Centre Design & Technology of the Saxion University of Applied Sciences has started the project *Veiligheid op de Werkvloer* ("Safety at Work") in 2011. The objective of the project is to increase safety at the workplace by applying and combining state of the art artifacts from information and communication technology, industrial design and high-tech functional materials. In a previous document (van Houten & Teeuw, 2011), factors that influence safety at work are presented, and specific safety-related issues at companies within the project are discussed. Additional documents discussed the state of the art on personal protective equipment (Brinks & Luiken, 2011), situational awareness technology (Van Leeuwen & Griffioen, 2011), and persuasive technology (Teeuw & de Boer, 2011) for protection at the workplace.

A line of research was proposed concentrating on the following two overall research questions:

1) How can we enforce safe behaviour by adjusting the environment people have to work in, and
2) How can we detect risks at work, and make them visible so that workers can avoid dangerous situations.

In this document, we provide the methodological background for research that will be executed in the Safety at Work project. This document combines several project deliverables as defined in the overall project plan (Van Leeuwen & Teeuw, 2009): validation techniques and methods (D5.1.1), performance indicators for safety at work (D5.1.2), personal protection equipment methods (D2.1.2), situational awareness methods (D3.1.2), and persuasive technology methods (D4.1.2).

In Chapter 2, we will present a general methodological approach to enable us to provide an answer to the research questions stated above. The main issue here is how we can reliably establish the effect of any intervention that is introduced to the work floor by applying a sound and valid methodology. In the subsequent chapters, we will look at specific methodological issues related to the three solution domains the project is focusing on: personal protection equipment (Chapter 3), situational awareness (Chapter 4), and persuasive technology (Chapter 5). The involvement of students – specific to this project – is discussed in Chapter 6. We end with concluding remarks in Chapter 7.
2. Approach

Ynze van Houten

Experimental design

The research questions as defined above point us to an experimental approach, as we want to be able to prove that the treatments/interventions we envision really work, meaning that they – and nothing else – have enforced safe behaviour. In general this means we want to test the hypotheses that we caused a difference in safe behaviour by the interventions we implemented on the work floor. For this we need to collect data about the work situation before the intervention (baseline) and after the intervention (effect), measure whether there is a difference, and make sure that the difference is very likely to be caused by our treatment/intervention. For the latter a control group is necessary, to rule out that the changes were caused by other factors than the intervention. Ideally, participants are assigned randomly to the experimental and control group, although in practice this will be hard to accomplish in a real-life setting (making it a quasi-experimental design).

![Experimental research design](image)

An ideal outcome of this approach is displayed in the following chart. In the “before” measurement, both the experimental group and the control group have scored about the same on a particular safety measure. After an intervention has been introduced to the experimental group (e.g., warning signs, protective clothing, etc.), the two groups are scored again on the same safety measure. Now it can be seen that the experimental group has a higher score on that measure (which hopefully is statistically significant). This is very probably due to the intervention, and not some other factor, otherwise the control group
would have shown the same increase. Only when some other factor only affected the experimental group (e.g. they got a new manager stressing safety procedures, and the control group did not) it might be wrong to conclude that the intervention caused the effect on safety. This example makes clear why it is important that experimental group and the control group preferably are similar (regarding composition and characteristics) and subject to the same factors.

![Effect due to intervention](image)

**Figure 2. Hypothetical outcome of the proposed research approach, displaying a positive effect of an intervention for the experimental group.**

In practice (and often for practical reasons), baseline measurements are “forgotten”, no control groups are used or control groups differ too much from experimental groups, there are confounding variables also affecting the safety situation, etcetera. This makes it hard to prove that an intervention does or does not have effect on safety at work. The set-up described here is what should be strived for to be able to do so.

**Defining research questions in real–life contexts**

Research in the project *Veiligheid op de Werkvloer* (“Safety at Work”) is executed in a real–life context. Based on previous research (van Houten & Teeuw, 2011), initial cases were defined. In the next step, these need to be more specified. This has to be done by close examination of the current situation at company sites, focusing on specific safety–related problems workers are faced with (in other words, a risk assessment). Techniques to identify safety–related problems include observation of current situation (unsafe situations, high–risk...
employees), consulting company records (analysis of accidents and absenteeism), and interviews (including retrospective analysis of (near-) accidents).

The European Agency for Safety and Health at Work (EU-OSHA, 2012) has made many risk assessment tools and methodologies available to help enterprises and organisations assess their risks. The choice of method will depend on workplace conditions, for example the number of workers, the type of work activities and equipment, the particular features of the workplace and any specific risks. The most common risk assessment tools are checklists, which are a useful tool to help identify hazards. Other kinds of risk assessment tools include: guides, guidance documents, handbooks, brochures, questionnaires, and "interactive tools" (free interactive software, including downloadable applications which are usually sector-specific). These tools can be either generic or branch/risk-specific. The Agency has developed a risk assessment tools database with tools from all over Europe. These tools are free and available online (EU-OSHA, 2012). The database is regularly updated with new tools.

For unsafe situations at the company sites, it is needed to establish an idea of 1) how high is the chance the unsafe situation can cause injury; 2) how serious can these injuries be; and 3) how often are (how many) employees exposed to these unsafe situations. There has to be a focus on unsafe situations where the risks can be reduced by applying an intervention of the type available in the project: personal protective equipment, situational awareness technology, and/or and persuasive technology.

After the risk assessment, for each case in the project there has to be a clear definition of a) the risk situation within each case that will be countered, and b) the type of intervention that is needed. This leads to the definition of a research question, which will have a general format like: “Does the introduction/application of ______ (the intervention) lead to a decrease of ______ (unsafe situations)?”

**Designing and implementing the intervention**

Based on clear case definitions, an intervention is planned with the aim to improve safety. In some cases, this may involve a change in the design of certain objects or of the working environment. When the intervention is applied to the working environment, it needs to be optimised for the situation and error-free. Ideally, the interventions are developed following an *iterative design approach* (see also Figure 3). This means that the ultimate design of the intervention is a result of several test-adjust cycles, both in laboratory and real-life contexts (in this case, the work floor). Especially when humans somehow have to interact with the
intervention, this will require a development approach involving users at several stages of design. This way the situation can be avoided that the intervention has no effect because of, for example, bad design, errors, or usability issues.

User-centred design (UCD) is a design philosophy and a process in which the needs, wants, and limitations of end-users of a product are given extensive attention at each stage of the design process (UCD, 2012). It can be characterized as a multistage problem solving process that not only requires designers to analyse and foresee how users are likely to interact with a product, service, or safety enhancement, but also to test the validity of their assumptions with regards to user behaviour in real world tests with actual users. Applying the UCD approach in the product development process increases the probability that the product offers added value to users and will be more usable.

In educational contexts, technological developments and their probable uses are being studied by students. In an applied context (like in the project described here) this may lead to the situation that the solution is trying to find a problem, instead of the problem is trying to find a solution. Because it is harder to adjust a problem than to adjust a solution, this may involve a risk, as this may lead to sub-optimal matches between problems and solutions. An iterative approach where the solution is optimised for the safety problem is essential here.

**Evaluating in a real-life context**

Within this project, the ultimate goal is to evaluate the effectiveness of interventions in real-life contexts. Evaluating in real-life contexts is central to the idea of Living Labs (EC-ISM, 2009). Several definitions of what a Living Lab is exist. Eriksson et al (2005) define Living Labs as a research and development methodology whereby innovations, such as services, products, application enhancements, but also safety enhancements, are created and validated in collaborative, multi-contextual empirical real-world settings. Living Lab
experimentation strives for the same level of observation as is common in, for example, a usability lab, but in an organic, multi-contextual space, such as the working place. An overview of Living Lab methodology can be found at the Living Labs Knowledge Centre (EnoLL, 2012).

**Domain methodology**

Specific designing and implementation issues for the three solution domains the project is focusing on are discussed in the respective chapters: personal protection equipment in Chapter 3, situational awareness in Chapter 4, and persuasive technology in Chapter 5. For each domain, we describe background theory, the general research methodology, the design process of interventions, and evaluation methods.
3. Specific methodology issues related to personal protection equipment research

Ger Brinks

Background theory

Personal protective equipment refers to any material or system worn or applied by a professional in his workspace that protects the worker from possible harm or injury induced by his working environment. Examples include clothing, shoes, gloves, and helmets. Personal protection spans a vast area of hundreds of different applications of materials and systems applied and tuned to specific working conditions. From a materials and systems point of view, it represents an area of enormous complexity because of the many differences between the various working conditions.

The current research focus is on protective textiles/clothing with special attention for compatibility of all items and for fit. Comfort is a key issue. If we consider the position of a person in a working environment we can distinguish some typical characteristics or interactions where protective materials or systems interfere:

1. Interaction with the machine or object that is being used or worked upon
2. Interaction with the working environment
3. Interaction between co–workers/colleagues

The functional characteristics of PPE depend on the tasks to be performed, thus for development of these systems a task description is needed. High levels of protection can be realized, but generally at the expenses of comfort, ergonomics, and extra costs. Therefore functional properties are defined based on the most important / most dangerous tasks.

It should be noted that much textile research is of an applied character that should be distinguished from pure scientific research into the fundamentals of textiles. From fibre/filament to yarn to cloth, followed by finishing and assembly into end products: each stage can be executed in numerous ways, making the full textile manufacturing process a fascinating yet extremely broad area of activity. In addition, the way a certain a detailed process step is executed influences, or even determines, the properties and application potential of the final products. For the results of textile research usually a direct application is sought in a new product or process or patentable material or technique. But the multiple layers in the production process of textiles is what makes textile research so complicated, unique, specific and relevant. One can design/choose in every layer of the process: Raw
material, filament process, yarn process, fabric making process, finishing, confectioning, ornaments/utilities, adding features (electronics/modules/shapes/designs/interfaces), and the like. All these aspects influence the research set up and can add complexity in development routs towards the final product, service of solution. The huge amount of alternatives for how to solve or attack a problem make textiles unique.

For a more elaborate discussion on personal protective equipment, see Brinks & Luiken (2011).

**General research methodology**

The starting point for describing the textile research methodology is the process/structure presented below.

![Research Structure Diagram](image)

**Figure 4. General research process**

Usually a problem or question is defined by society or the industry, in our case the textile industry. These questions often address immediate problems or issues from their contact with customers or end users and for which no immediate responses or solutions are available. This may be because the knowledge currently available is not sufficient to answer the question or solve the problem. So research is conducted. While discussing, we "translate" the problem into a specific research question or hypothesis. The character of the questions is like: how can we ... .. or: what should we ... .... Hypotheses have the character of: we think
or feel that something is so or so…. can this be verified or refuted? For more detailed descriptions, see Rip (1978) or Koningsveld (1978).

In the context of the Safety at Work project, our work package is aimed at developing textile solutions for PPE applications. Thus the problem definition is to a large extent based on the findings of the other WPs. It also means that our research is part of the total research aimed at solving specific problems. The next step: briefing is therefore of utmost importance since there it is determined what our specific research objectives will be.

Iteratively in a discussion a briefing or project – or study description is made. Here the question will be further specified and the first references are shared. The question is split into sub-questions or split hypothesis. What is the desired outcome of the investigation, what textile raw materials do we include in the study, which ones not and why or why not. Material characteristics or product specifications sought are to be established and the boundary conditions for the textile processes are established. The required expertise is established. Often we use a product- or work breakdown structure to enable us to define work packages and the work and expertise becomes clear to all concerned. Also, a time plan is made. In the world of textiles, there are many possible production systems and unit operations imaginable. We seek to form an impression of what textile processes are needed to take this into account for up scaling of processes.

Our task is the development of enabling technology for the support of the ultimate systems. The textile group integrates required solutions into the textile substrate, whereby the textile itself acts as a carrier for intelligent functions. In this stage we already form an idea of our route of approach: some sensor or actuator functions can be incorporated as a device, meaning a package electronic components integrated onto a printed circuit board of minimal dimensions. Another group of solutions require surface modification since the sensor or actuator function will be incorporated by coating technology or by digital surface modification. Research is aimed at developing relevant formulations and application systems. From the literature, knowledge and experience we know how to incorporate these into textiles in a general way. Our task is to make this specifically applicable for the situations described in the other WPs.

Ultimately, this discussion and its explorations lead to a plan of attack. Here all major activities are itemized and listed along with who, what, when, how, budgets, etc., also the most important literature references are mentioned. In this plan the route toward the defined solution is described. In textiles we have to take into account the important issues mentioned in the introduction, but also those of in use behaviour such as maintenance,
usually laundering. For smart textiles we also know of developments that follow the subdivision approach for maintenance: all electronic parts are grouped together in such a way that they can be separated from the garment. The garment is cleaned and the electronic parts are maintained. After cleaning the systems are reassembled. Coatings or modified surfaced require a different approach: after cleaning the integrity is assessed and restored where necessary. We will closely follow the results of current research projects in this area, like the EU FP7 project “wash and load” partly conducted by the chair EFSM at the University of Twente. In this stage we also have to deal with EN, ISO and NEN norms. These specify the legal requirements of textiles for use in PPE conditions. Reflection and flame retardant properties are examples of this. Compliance to these norms is mandatory. This will be taken into account in our research.

It is important to note that the nature of our research is strongly application-oriented, and therefore has its own approach and dynamics, while maintaining academic standards and values (see e.g., Nederhof de Weerd et al, 1994, Weggeman, 2008. Roussel et al 1991). Subsequently preliminary work for the study is executed. In the case of textile research we spent quite some time on visits to research institutes in this field, especially the institutes in Germany and Belgium who are leading in this area. In addition we take part in conferences in the textile area in order to get ideas of what is happening (ETP congress, AUTEX congress) and what overlaps with the present investigation. In the network we exchange views with fellow researchers in both applied and fundamental research. Also, the open patent literature is reviewed. Point of attention: Application oriented research is closer to market than basic research. This affects the degree of openness of discussions about our research. There may be huge financial interests at stake.

In the next stages, the specific textile products are designed and tested, both in laboratory as in the applied setting.

**Designing personal protective equipment**

At this stage the preparations for the experimental work are being made as well. Materials are selected, and other consumables and chemicals are selected, and experiments are devised. Measurement methods are selected and discussed with fellow researchers or with experienced leading researchers.

Then the experiments are conducted, tests system and demonstrators are built, all in compliance with the boundary conditions described above. All observations are recorded in a log or notebook and may be supplemented by sketches or photographs. These
experiments consist of making small size samples and subject these to tests. Usually series of test samples are made in order to interpret the results in a mathematical way, and statistical analysis is part of this. The samples are made using predefined materials based on materials currently used in PPE. Electronic components are incorporated manually or using embroidery machines. Coatings are applied by lab scale squeegee systems and/or digital printing. The testing is done by specific set up like measuring conductivity or colour intensity with standard lab equipment. Usually this work is executed by junior assistants and/or students. Supervision takes place by senior researchers. The final responsibility lays with the head of the research group, the professor of the responsible chair.

The results of the experiments are analysed whereby as a start it is determined whether all measurements and tests have been conducted according to proven methods and validated testing. The data are analysed using statistical methods. The results are summarized and initial conclusions are made. In consultation with the supervisor or designated senior colleagues it is determined whether the research is properly conducted and the experiments are correct. There is discussion on the correctness of the conclusions and a draft report prepared.

Usually series of test samples are made in order to interpret the results in a mathematical way and drawing of graphs to be able to draw logical conclusions. Statistical analysis is part of the analysis. In our application oriented approach we also make predictions about larger scale production. The basis for this is discussing the results with professionals in the sector and by creating a number of ideas of the equipment needed for large scale production. It should be noted here that compliance with EN, ISO, and NEN norms is part of this assessment stage.

After feedback to the commissioner or the "formulator" of the hypothesis a final report is made, possibly followed by an external open publication or patent application. It is determined to what extent the question or the questions have been answered and what follow-up questions or new hypotheses can be formulated. The client can decide to use the results in their own organization to enter into a more market-oriented product development process or to adapt production processes.

In the framework of the Safety at Work project the results are discussed with the other work packages to establish if the problem was solved or the requirements have been met. If accepted, the reports are finalized.

The following equipment is at our disposal:

At the Academy Creative Technology / Life Science Engineering and Design:
• Standard lab equipment from pH meters to agitators, glassware, etc.
• Looms
• Knitting machines
• Sewing machines
• Confection workshop
• Testing equipment such as test stands, wear meters, standards
• Dye equipment

At Open Innovation Centre Advanced Materials (OICAM):
• Advanced pilot-scale coating line
• Extrusion Lines / filament spinning

At our “own” lab:
• Embroidery Machine
• Sewing machine
• Digital printer
• 3D printers
• Limited formulation lab
• Microscope
• Resistance / currency meters
• Smart auxiliary materials

Through fellow researchers at the EFSM UT is an even wider range of devices and test methods available. Also parts of the work can be farmed out to research institutes at home and abroad, such as DP measurements.

**Evaluating personal protective equipment**

In the field of textile testing there are a large number of guidelines and standards that must be met to reliably analyse data and to be able to compare results with the literature values, benchmark experiments in the literature are carefully examined. (See e.g. Saville (1999) and BISFA guidelines, or Manual of Functional & Technical Textiles Certification by the Taiwan Textile Research Institute).

For example, for a bleaching experiment we use standards to indicate degree of whiteness. These are internationally recognized standards and should be used to make meaningful communication possible. Another example: enzyme activity is determined by internationally recognized methods. It cannot be varied without the risk that results are not comparable anymore and therefore meaningless. Test equipment must be calibrated against standards (e.g. pH meters) and analysis methods must be validated so that the secured results show the reality.
As an example to illustrate the importance of evaluation some typical remarks made by wearers of fire protection work wear are "The uniform is too hot during task performance", and "The uniform does not fit". Both are critical comfort issues that hinder proper functioning of in this case fire-fighters. For meaningful evaluation we have to consider heat balances and the effect of wearing these uniforms or more general work wear on:

- Metabolism
- Heat Storage
- Radiation
- Convection (conduction)
- Evaporation

Daanen (2009) developed an experimental set up to evaluate risk factors in work wear. Risk factors include:

- High temperature
- High humidity
- No wind
- (Solar) Radiation
- Insulating clothes
- High exercise intensity
- Worst case: work in impermeable clothing

Daanen also developed a comprehensive model combining several factors of strain on the human body in critical working environments (see Figure 5). The conclusion from his work is that we have to 1) develop methods to alleviate heat strain (assist human systems); 2) improve natural ventilation through clothing design (pumping effect); 3) incorporate heat
strain sensors in fitting clothing systems; 4) improve knowledge about acceptability of clothing systems; and 5) standardize PPE evaluation based on human factors.

In other words: evaluating PPE work wear on safety only solved part of the problem but may create additional issues. The above example serves as a good example of the need for proper evaluation.
4. Specific methodology issues related to situational awareness research

Henk van Leeuwen, Piet Griffioen, Tatiana Goering-Zaburnenko

Background theory

“To know what is going on” is the simplest description of situational awareness. A more formal definition is “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future” (Endsley & Garland, 2000). This definition consists of three ingredients: perception, comprehension and projection. To enable perception human senses and sensors play an important role. Perception delivers data from the sensing devices. To come to comprehension data and information from several sources must be interpreted to understand the situation. On the basis of this comprehension expectations of the situation in the near future can be derived and appropriate actions can be chosen. In this process the interpretation and decision making process can be a human concern or it can be automated. In many cases a mix of human and computer activity is the case.
Situational awareness is no goal in itself. It is helpful to make decisions and start actions to reach safety goals. Situation Awareness starts with the perception of the situation by means of (human) sensors. In the next step the raw sensor data is analysed and combined providing understanding of the situation. The third step is decision making by reasoning about the situation and the impact of specific actions. The process along which situation awareness is accomplished is illustrated in Figure 6. For a more elaborate discussion, see Van Leeuwen & Griffioen (2011).

The research methodology for Situation Awareness is along these lines of sensor technology, information processing including presentation, and reasoning. The research is not pure scientific but rather practical by the combination and application of new and existing products and techniques in the context of safety at work.
General research methodology

The generic research methodology and research process is shown in Figure 7. This generic process is tailored for Situation Awareness and safety at work as described below.

The input consists of stakeholder needs and a problem description. The stakeholder is informed during all steps of the research process enabling early feedback.

In the orientation phase the problem is analysed and a solution strategy is chosen. The solution strategy involves sensor technology, information processing and/or reasoning models. This is dependent on the type of problem. Is it an incidental problem or a structural problem? Is it lethal or not? Is it a time critical problem in the sense that immediate, real time response and action is required or not?

Based on the solution strategy, the design phase formulates requirements for the experimental set-up and defines hypothesis. In this phase it is determined whether the evaluation methodology is knowledge based, performance based or even both. This phase defines also the dependent and independent variables of the test approach, defines the baselines and the planned interventions. The design phase takes also into account product policies and roadmaps. It determines the type of (multimodal) sensors and associated information processing that is required and whether reasoning models are needed. Sensors might be fixed, mobile or wearable (link with PPE), depending on the type of problem. The
design phase defines also the way information and possible warnings are presented to the user.

Based on the requirements and test objectives of the design phase, the development phase produces the experimental set-up and finalizes the solution definition based on experimental constraints and measurement techniques. In this phase it is also determined whether or not (new) developments are needed or off-the-shelf (COTS) solutions are used. Especially in the area of sensor technology and sensor networks, COTS based solutions are preferred. The development might consist of new and clever algorithms that combine (multimodal) sensor data.

In the verification phase the experiment(s) are executed and iterations are made when necessary. Verification starts with baseline measurements, afterwards interventions are introduced. Measurements are performed and experimental data is collected and analysed. Measurements can be knowledge based or performance based, or both. The data is (statistically) analysed against the earlier formulated hypothesis.

In the validation phase the test results are validated against the stakeholder needs. This can be in the form of a report or in the form of a demonstrator.

Within the domain of ICT, Johnson (2012) distinguishes a number of research methods, including Implementation driven research. In this approach a system is built to explore if the system is feasible and if we can do measurements to prove some hypothesis. This type of research has its own restrictions that are correlated to the system or the (good or bad) way the system is developed. This method has a great similarity to system development. The combination of both is reasonable, but the research question is leading when doing research. The engineering is instrumental and subordinate to the research.

Research methods in situation awareness are closely connected to research in ICT and artificial intelligence, but in the case of situation awareness more attention should be given to user awareness and attention. This can be done by experiments and observations.

**Designing situation awareness enhancements**

Interventions can take place at all three levels of Situation Awareness. In the perception phase emphasis will be on new sensor technology and multi-modal sensor networks. Depending on the problem phenomena are singled out that are important to know. To observe these phenomena sensors are chosen that produce data from the phenomena can
be derived. Sensors should be placed on the right place and used at the right time to get useful data. Sensor data must be communicated to the right processing unit. It must be considered if all data is communicated or that part of the processing and filtering is done locally. In the comprehension phase smart and sophisticated algorithms can be introduced to interpret what is going on. The interpretation depends largely on the semantics that are connected with the data. A clear picture of the situation is constructed. Visualisation can be very helpful in this phase. Think of augmented reality. In the projection phase what–if type of probabilistic reasoning techniques are introduced. Thinking in scenarios with a high probability can be helpful.

**Evaluating situation awareness**

There are several methods for evaluating Situation Awareness. These methods can be roughly divided into knowledge–based and performance–based (see also Figure 6.).

*Knowledge based* methods measure the level of understanding of the situation. An example of a knowledge based method is the Situation Awareness Global Assessment Technique or SAGAT (Endsley, 2000). SAGAT is performed in an experimental context and freezes the situation at random times and queries the subjects about their understanding of the situation. *Performance based* methods measure the user action in terms of timing, essentials and effects under realistic conditions. For testing interventions, final decisions must be based on whether the user will be provided with sufficient situation awareness to perform the correct actions, which performance–based techniques measure directly. Knowledge–based measurement techniques, on the other hand, can only make reasonable guesses about the likelihood of the user's actions given their knowledge state.

Measuring situation awareness in the context of safety at work is not an easy job because of the relatively large number of factors that have impact on situation awareness, see for instance the SHELL model (Hawkins, 1987). These factors consist of applicable safety rules and guidelines, equipment interfaces, the interaction with the environment, the interaction with co–workers, personal knowledge and experience and the state of mind. These factors are not independent of each other. The objective of the experiment (the hypothesis) is leading for the design of the experiment, for the design of interventions and the associated measurements. Interventions should be carefully designed given the objectives and should not include too many factors but also not isolate important factors. Otherwise the measurements and therefore the result of the experiment can become (statistically) biased.
**Example: Sensor shirt**

We end this chapter with an example of how the research methodology is applied. In the project Safety at Work we are going through the stages displayed in Figure 7, sometimes simultaneously, mostly iterative and building the device incrementally.

In the beginning of the project (the orientation phase) the requirements are determined by way of interviews or discussions with the party concerned, e.g. fire brigades and sport clubs. A full report of example interviews (in Dutch) is to find in the report of Wiering (2012). In the case of the example it was clear that there is a demand for a product that can determine physical condition of a person such as concentration, fatigue, temperature, perspiration, position, movement characteristics and heart rate. This is relevant for fire brigades because one wants to determine if a person is up to making mistakes or that his physical condition is in danger. That also applies, in other degree, for athletes. The question is what kind of physical condition can indicate loss of concentration, overheating or exhaustion? When it becomes so critical that the person is up to making mistakes that can lead to an accident? Or that bodily harm can be developed.

In the described case Wiering (2012) has chosen to measure heart rate, temperature, breathing and sweating. For example, if a person begins sweating and the heart variability rate goes up that can indicate stress and can lead to making mistakes. On the other hand, low heart rate and low body temperature, and much perspiration may be a sign of tiredness.

The second phase is the design phase at which requirements are determined and hypotheses are made. The design phase was done and is also described by Wiering (2012). The hypothesis is that if we know temperature, heart-, sweat- and breathe rate, then we can estimate the stress factor.

Requirements: we need sensors that are reliable, small and work at low power. The sensors should measure the parameters mentioned in the hypothesis. The sensors should be placed as close to the body as possible. By preference the sensors are washable.

Design: Integrate the sensors in a tight, flexible T-shirt so that all the measurements can be done close to the body (to make sure that as little as possible interference is introduced) with a minimum of discomfort for a person. Used sensors are as small as possible (for optimal personal convenience and for minimal power consumption).

Test approach: choose sensors and try them independently to see if they can serve our purposes. Research of a suitable sensor is done for each of the characteristics that need to
be measured (heart rate, sweat rate, temperature, etc.).

The third phase, development, is done by engineers. It is known what type of product is required; the question is which sensors can be used to get required results. The next step is to select the sensors and perform experiments with sensors in a T-shirt to decide which sensors give the most reliable data.

Verification, the next phase. Once the experiments are done, they have to be checked. Are the data accurate, valid and sufficient? How can the data be filtered, communicated, processed, stored and analysed? Is there a reference point to check if the data we gathered are correct? Can we make conclusions? Do the data verify our hypothesis?

The last phase, validation: a product is made. But does this product satisfy the need of the stakeholder? Is that what was needed and described in problem definition?

It can also be the case that different phases are done by different people and phases’ sequence can change (e.g. experimenting with sensors (development phase) can be done in design phase). Furthermore, before the system is build and a choice of sensors can be made, one needs to know exactly what has to be measured. If, along the way, other type of information is needed (e.g. other measurements has to be made to determine stress factor more accurately), one needs to start again: choose the sensor, test of that actually work, adapt it (build it in) to the system, etc. An iterative process is normal.

To summarise the steps in the process: 1) what needs to be specified (stress factor, fatigue), 2) how can it be measured (which sensors are needed), 3) how can that be implemented, 4) how the data have to be collected and 4) how the data have to be interpreted.
5. Specific methodology issues related to persuasive technology

Johannes de Boer, Karin van Beurden

Background theory

Since the early 1900s, the belief of how to persuade other has been the subject of many studies, and has been very popular in the media. The use of propaganda during the world wars, the raise of mass media, and the accessibility of digital media to most worldly citizens in the past decade has led to many studies and understanding of the power of persuasive messages. Kilbourne (1999) states that “the average American is exposed to at least three thousand ads every day and will spend three years of his or her life watching television commercials” (p. 58). In our lives, we are immersed with messages of persuasion. We believe that having an understanding of how persuasive messages work is essential for influencing safe behaviour.

Persuasion is often defined as “Human communication that is designed to influence other by modifying their beliefs, values, or attitudes” (Simons, 1976). According to O’Keefe (1990) there are three requirements to make something persuasive. First, persuasion involves a goal and the intent to achieve that goal on the part of the message sender. Second, communication is the means to achieve the goal. Third, the message recipient must have free will. When the third requirement is not met, often the message is not considered persuasive, but coercion. The line between these two is very thin. This can be seen, for example, by the existence of coercive persuasion (also known a brainwashing, mind control or thought reform). Therefore, good use of persuasion is neither accidental nor coercive, but inherently communicational.

In their book, Shell & Moussa (2007) argue for a four–step approach to strategic persuasion:

1. Survey your situation
   Make an analysis of the persuader's situation, goals, and challenges that are faced in the organization.

2. Confront the five barriers
   Five obstacles pose the greatest risks to a successful influence encounter: relationships, credibility, communication mismatches, belief systems, and interest and needs.
3. Make your pitch

People need a solid reason to justify a decision, yet at the same time many decisions are made on the basis of intuition. This step also deals with presentation skills.

4. Secure your commitments

In order to safeguard the long-time success of a persuasive decision, it is vital to deal with politics at both the individual and organizational level.

We describe four well known theories that can be used to influence safe behaviour, but can also be used to form public relations campaigns, presidential campaigns, or convince a costumer: social judgment theory, the elaboration likelihood model, cognitive dissonance, and the narrative paradigm.

**Social Judgment Theory**

Created by Sherif & Hovland (1961) and coming from the field of socio-psychology, Social Judgment Theory (SJT) focuses on the internal process of an individual’s judgment with relation to a communicated message. The theory suggests that knowing someone’s attitudes on subjects can provide you with clues on how to approach a persuasive effort.

People make evaluations about the content of messages based on their anchors. In addition to this anchor, each person’s attitudes can be placed into three zones: latitude of acceptance, latitude of rejection, or latitude of non-commitment. The first includes all the ideas someone finds acceptable, the second category includes all the ideas someone finds unacceptable, and the third category includes ideas for which someone has no opinion (neither accept nor reject).

SJT proposes the idea that persuasion is a two-step process:

1. Individuals hearing or reading a message and immediately evaluating where the message falls within their own position. position (Level of Ego–Involvement) and in what latitude
2. Individuals adjusting their particular attitude toward (assimilation effect) or away (contrast effect) from the message they heard.

The aim of the theory is to explain how attitudes may change in the communication process. According to Sherif et al. (1982), the attitude change will be less likely to occur if the gap, between attitudes a person already has and the attitude advised by the message, is big. The theory holds that any person hearing a message will position it on an attitude scales based on his personal judgment. The attitude scale is pre-set in our mind prior to receiving the message and it is composed by the three different zones.
Elaboration Likelihood model

Elaboration Likelihood model (ELM) sees persuasion primarily as a cognitive event. It relies on the fact that the targets of persuasive messages use mental processes of motivation and reasoning to accept or reject these messages. According to (Petty & Cacioppo, 1986) there are two possible routes of influence: the central route and the peripherally route.
The more complex of these two, the central route (also referred to as an elaborated route) processes require a great deal of thought, and therefore are likely to predominate under conditions that promote high elaboration. Centrally routed messages typically include a wealth of information, supporting evidence and rational arguments. These types of messages are likely to create long-term change for the recipient. According to ELM, centrally routed message only succeed in this change when two factors are met: (1) the target must be highly motivated to process all the information, and (2) the target must be able to process the message cognitively.

Elaborated messages are ineffective when recipients are not capable and interested in the information. When motivation or ability is lacking in the target recipients, the peripheral route can be used. Peripheral messages rely on a receiver’s emotional involvement, they also persuade through more superficial means. The largest drawback is that peripheral messages lead only to short-term change, at best.

**Cognitive Dissonance Theory**

Cognitive Dissonance Theory (CDT) was created by Festinger (1957). It explains that persuasion is not simply the result of injecting new or refined beliefs into other. According to CDT influence is often an intrapersonal event, occurring when incongruence between attitudes and behaviour creates a tension that is resolved by altering either beliefs or behaviours. The idea behind this principle is that individuals have an abiding need to be consistent in their attitudes and behaviours; they want to feel unified in thought and action.
Therefore, we strive to decrease tension changing our original thought, giving strength to the opposing thought, or letting go of the behaviour.

**Narrative Paradigm**

Narrative Paradigm (NP) is coming from the idea that narration (persuasion through storytelling) is a strong influence of behaviour. It argues that all meaningful communication is a form of storytelling or giving a report of events (see narrative) and so human beings experience and comprehend life as a series of on-going narratives, each with their own conflicts, characters, beginnings, middles, and ends. Fisher believes that all forms of communication that appeal to our reason are best viewed as stories shaped by history, culture, and character, and all forms of human communication are to be seen fundamentally as stories.

**Persuasive technology**

Persuasive technology is a research area that became well known during the late 90’s and early 00’s due to the work of B.J. Fogg of the Stanford University. Formed after discussions during CHI’97 and later conferences, persuasive technology is often defined as “any interactive computing system designed to change people’s attitudes or behaviours” (Fogg, 2003). Other definitions of persuasive technology are hard to find, because most authors and researchers use the definition given by Fogg.

Besides classifying the different kinds of persuasive technology, it is also important to know how behaviour can be changed. A model that can help accomplishing this is the Behaviour Grid developed by Fogg (Fogg & Hreha, 2010). Fogg describes 15 ways behaviour can change. The purpose of the grid is to help people think more clearly about behaviour change.
The Behaviour Grid has two axes. The horizontal axis describes the five flavours of behaviour. The vertical axis categorizes the duration of the behaviour.

**Axis of duration**

According to (Fogg & Hreha, 2010), behaviour can span over different periods of time: one time (dot behaviour), span of time (span behaviour), or on-going (path behaviour). Dot behaviour is done only once, like making a detour while driving home. Other examples are choosing not eat meat one day, drinking a cup of decaffeinated coffee this morning, or wearing a pair of normal shoes instead of safety shoes to work today. Designing for dot behaviour means that are no specific long-term implications devised for the product. Therefore, there is often a lower behaviour activation threshold.

Span behaviour is behaviour that is done over a period of time. Designing for this type of behaviour requires thinking about regular triggers, because people must stick to this behaviour for a longer period of time. Examples of span behaviour are: wearing extra safety gear for a whole week, not taking sugar in your coffee for a month, or using another entrance for entering the office for a longer period of time.

---

**Figure 10: Fogg’s behaviour grid with safety examples (http://behaviorgrid.org/).**

<table>
<thead>
<tr>
<th>Dot behavior</th>
<th>GreenDot</th>
<th>BlueDot</th>
<th>PurpleDot</th>
<th>GrayDot</th>
<th>BlackDot</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-time</td>
<td>Do NEW behavior one time</td>
<td>Do FAMILIAR behavior one time</td>
<td>INCREASE behavior one time</td>
<td>DECREASE behavior one time</td>
<td>STOP doing a behavior one time</td>
</tr>
<tr>
<td></td>
<td>Install solar panels on house</td>
<td>Tell a friend about eco-friendly soap</td>
<td>Plant more trees and native plants</td>
<td>Buy fewer cases of bottled water today</td>
<td>Turn off space heater for tonight</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Span behavior</th>
<th>GreenSpan</th>
<th>BlueSpan</th>
<th>PurpleSpan</th>
<th>GraySpan</th>
<th>BlackSpan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>Do NEW behavior for a period of time</td>
<td>Do FAMILIAR behavior for a period of time</td>
<td>INCREASE behavior for a period of time</td>
<td>DECREASE behavior for a period of time</td>
<td>STOP a behavior for a period of time</td>
</tr>
<tr>
<td></td>
<td>Try carpooling to work for three weeks</td>
<td>Ride a bike to work for two months</td>
<td>Recycle more of household waste for one month</td>
<td>Take shorter showers this week</td>
<td>Don’t water lawn during summer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Path behavior</th>
<th>GreenPath</th>
<th>BluePath</th>
<th>PurplePath</th>
<th>GrayPath</th>
<th>BlackPath</th>
</tr>
</thead>
<tbody>
<tr>
<td>From now on</td>
<td>Do NEW behavior from now on</td>
<td>Do FAMILIAR behavior from now on</td>
<td>INCREASE behavior from now on</td>
<td>DECREASE behavior from now on</td>
<td>STOP a behavior from now on</td>
</tr>
<tr>
<td></td>
<td>Start growing own vegetables</td>
<td>Turn off lights when leaving rooms</td>
<td>Buy more local produce</td>
<td>Eat less meat from now on</td>
<td>Never litter again</td>
</tr>
</tbody>
</table>
Lastly, path behaviour describes behaviour that is done from now on. They are permanent in nature, and triggers must be used, until it becomes part of someone’s routine. Habits that can be created using path behaviour are: biking to work every day, not drinking coffee anymore, thinking more consciously about energy consumption at home. This type of behaviour is hard to induce, and constant triggers must be used to make the behaviour a habit.

*Axis of flavour*

(Fogg & Hreha, 2010) distinguish five different flavours of behaviour. These flavours were all given the name of a colour. The five flavours are: green, blue, purple, grey, and black.

Green behaviour is behaviour new to people. Because it is new to people it may require to make the intended behaviour very simple, connect it to known and existing behaviour, and to reduce anxiety about the new behaviour. Examples of green behaviour are: driving a car for the first time in your life, become a vegetarian, or start wearing safety goggles during dangerous tasks.

Blue behaviour is familiar for people. Designs for blue behaviour can draw on past experiences. They often do not need to be explained. Green behaviour can become blue behaviour when a person becomes familiar with a certain task or habit. Examples of blue behaviour are: walking to the supermarket, boiling water, and wearing a safety helmet when working on a building site.

The purpose of purple behaviour is to increase familiar (blue) behaviour. This can be done by increasing the duration or intensity, or by increasing the complexity level. For example: checking the safety equipment more frequently, or walking to the supermarket multiple times a day can both be categorized as purple behaviour.

With grey behaviour we start to describe behaviours that decrease over time. Grey behaviour means the decreasing of a certain type of behaviour in intensity, duration, or frequency. For examples: drinking fewer cups of coffee, paying less attention to safety, or using less toxic materials during work. Some type of behaviour decrease can also be seen as purple behaviour, because using less toxic materials can also be seen as gaining more awareness for the dangers of using toxic materials.

Finally, black behaviour is the ceasing of behaviour, for example, not drinking coffee anymore, not wearing safety helmets, and stop using certain toxic materials during work.
It is important to note that, depending on the target audience, different flavours can be assigned to the same behaviour. For example, when the ultimate goal is that every worker wears a safety helmet all the time; for some workers this will be green behaviour, for others blue or purple behaviour.

Fogg’s Behaviour Grid may help to focus only on relevant research for the project Safety @ Work. Ideally, all the research and solutions of Safety @ Work will focus on long-term (permanent) awareness on safety.

**General research methodology**

In our studies we define three consecutive phases to conduct our research. The first phase is analysis. In this phase methods like desk research, observations, user profiles, and personas are used.

The second phase consists of interventions. These interventions are targeted at behavioural safety. These interventions try to influence behaviour by addressing psychological aspects, physical aspects, or senses.

The third and last phase is testing. During this phase baseline measures, expert meetings, and placebo tests are used.

A method used in the first phase is the grounded theory model (Glaser & Strauss, 1967). Grounded theory appears to be contradictory to the normal scientific method. Instead of starting off with hypotheses, the first step is to collect data (through various methods). From the data collected, key points are marked with codes. The codes are grouped into similar concepts. From the codes, categories are formed. Those categories are the basis for the creation of a theory. One could argue that this is reverse engineering of hypotheses.

One of the goals of grounded theory model (GTM) is to formulate hypotheses based on conceptual ideas. Another goal is to discover the participants’ main concern and their process in how to resolve it. GTM does not aim to find the truth, but to conceptualize what’s going on. If the goal of a study is to work towards an accurate description, then another method should be chosen, because GTM is not a descriptive method.
Persuasive technology incorporates and builds on the results, theories, and methods of experimental psychology, rhetoric, and human computer interaction. It is often been referred to as a particular case of design with intent (Lockton, Harrison, & Stanton, 2010).

Most studies in the field of Persuasive Technology use experiments. Other often used methods are pilot studies, field studies, and crucial experiments. Because PT is frequently used to solve a particular problem; case studies (or case reports), interview, and naturalistic observation are also common in the field.

According to Thomas (2011), case studies are "analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods. The case that is the subject of the inquiry will be an instance of a class of phenomena that provides an analytical frame — an object — within which the study is conducted and which the case illuminates and explicates."

Naturalistic observation is used to observe subjects in their natural habitat without any manipulation by the observer. During this type of observation great care is taken to avoid any interference with the behaviour that is being studied. The main difference compared to many other forms of observation is that the environment is being manipulated or created by the observer.

From the field of human computer interaction (HCI) a huge number of methods can be used to study Persuasive Technology. HCI is the intersection of computer science, behavioural sciences, design and several other fields of study. The term was introduced by Card, Moran, and Newell (1986) in their book, "The Psychology of Human–Computer Interaction".

In HCI, activity theory is used to define and study the context in which human interactions with computers take place. Activity theory provides a framework to reason about actions in these contexts, analytical tools with the format of checklists of items that researchers should consider, and informs design of interactions from an activity-centric perspective.

A modern design philosophy, widely practiced in the field is user-centred design (UCD). This philosophy is rooted in the idea that users must take centre-stage in the design of any computer system. Users, designers and technical practitioners work together to articulate the wants, needs and limitations of the user and create a system that addresses these elements. Often, user-centred design projects are informed by ethnographic studies of the environments in which users will be interacting with the system. This practice is similar but
not identical to Participatory Design, which emphasizes the possibility for end-users to contribute actively through shared design sessions and workshops.

**Methodology for designing persuasive technology**

Until a few years ago, there were few examples of persuasive technology in daily life. In recent years persuasive technology has become more eminent in our houses, workplaces, and public space. We are increasingly more surrounded by devices and media that change what we think and how we act. Countless examples are available for researchers, and give them the opportunity to learn rapidly about persuasion and persuasive technology. When the occurrence rises that designers or researchers want to create an entirely new persuasive technology, this can be a challenge.

![Figure 11: Eight steps in early-stage persuasive design (Fogg, 2009).](image)

Many designers do not have experience creating products with a persuasive goal, and there is no proven design process. In order to prevent some of problems many design teams
encountered in recent years, Fogg proposes an eight-step design process for creating persuasive technology, as shown in Figure (Fogg, 2009).

Attempts to create Persuasive Technologies often fail. One problem is that many projects fail because they are too ambitious. Teams that are new to designing Persuasive Technologies should scale back their ambitions and save the difficult behaviours for later projects, after they learned to succeed in designing technologies targeted at more tractable behaviour changes. The eight steps are used to outline a path to follow in designing Persuasive Technologies that will increase the probability of success.

Step 1: Choose a simple behaviour to target
Fogg recommends choosing the smallest, simplest behaviour that matters. It doesn't need to be the final objective, but it can contribute to it. The goal needs to be very specific (for example: stretching 20 seconds a day, is part of the final objective to reduce overall stress). A large, vague goal can be broken down in two ways:
1) As an approximation of a larger objective;
2) As a first step in achieving the larger goal.

Step 2: Choose a receptive audience
Designers should choose the audience that is most likely to be receptive to the targeted behaviour change, and should be familiar with the technology channel. The goal of step 1–7 is to create a product that persuades someone (not everyone) to adopt the target behaviour. Once a design team has developed an intervention that is working, it can be expanded to users that are less receptive. Often early adopters or other adventurous people can be chosen as a target audience.

Step 3: Find what prevents the target behaviour
What prevents the audience from performing the target behaviour? There is always a combination of three categories:
1) Lack of motivation;
2) Lack of ability;
3) Lack of a well-timed trigger to perform the behaviour (easiest to create).
In most cases the persuasive technology must boost motivation, facilitate the behaviour, or both. Be aware that in case the target audience lacks both motivation and ability, the team needs to back up and rethink the previous steps.
Step 4: Choose a familiar technology channel
It is often difficult to determine which channel is best to choose. Basically, this depends on the results of the first three steps. In most cases this means that the design team cannot select an intervention channel until the first three pieces of the process have been completed. Teams should always try to use a channel that is familiar to the audience. In case that a channel must be used that is unfamiliar to the audience, this will take considerably more time.

Step 5: Find relevant examples of Persuasive Technologies
The team can start a search for relevant examples of persuasive technology for their project. Making educated guesses is a good approach, because companies often do not share their conversion data with outsiders. Also imitating methods of experts can be used.

Step 6: Imitate successful examples
The team should not be afraid of using something that is similar to other successful Persuasive Technologies. This requires insight from the team, because they need to come up with a way to adapt that success formula of the already existing product for their product.

Step 7: Test and iterate quickly
Multiple small tests will teach the team more than one big final test. Each test should take not more than a few hours. Because designing for persuasion is much harder than designing for usability, many attempts to change behaviours fail.

Step 8: Expand on success
If the persuasive technology works for the current audience, is can be expanded to other audiences. Or the target behaviour can be made more difficult.

**Evaluating persuasive technology**
The field of Persuasive Technology does not specify or limit measures. Often, measures comparable to usability studies and user studies are used. An overview can be found in the research methods library of the Saxion research centre Industrial Product Design (link: http://onderzoeksklapper.filab.nl/index.php?page=gebruiksonderzoek). The methods described in the library include: Context mapping, Usability testing, Focus group, Card sorting, Observation, Interview, Diary Study, Cultural probe, Heuristic evaluation, Contextual inquiry, etcetera.
6. Student involvement

*Henk van Leeuwen, Wouter Teeuw*

What is specific for the approach within the Safety at Work project is that the research methodology is for an important part carried out by students. Their participation has two sides. One is the practical research they bring in into the project. On the other side they are learning. This implies that in the project assignments they should learn how to manage their own research contribution. It is our explicit objective to deliver students with a critical research attitude. In this way, as also indicated by Borgdorff et al. (2007), the Dutch HBO may constitute an additional bridge between education on the one hand and professional practice on the other hand.

The British researchers Jenkins and Healy (2005) describe how research can be woven into a curriculum. There are two main drivers:

- The role of the student: learning by doing vs. learning by being taught.
- The role of research: emphasis on the research content vs. emphasis on the research process and problems.

This leads to four approaches:

- Research-led: education based on actual knowledge, the curriculum is structured around teaching current subject content.
- Research-oriented: education with focus on learning research methods, the curriculum emphasizes the teaching processes of knowledge construction in the subject.
- Research-tutored: education with focus on writing and discussing papers, the curriculum emphasizes learning focused on students writing and discussing essays and papers.
- Research-based: learning by doing research yourself, the curriculum emphasizes students undertaking inquiry-based learning.

The state of the art deliverables provided by the project (D2.1.1, D3.1.1, D4.1.1) fit into a research-led approach. The can be used by lecturers as current subject content in their teaching. This document as a methodological deliverable (D5.1.1) fits into a research-oriented approach. In general, the student projects are research-based with and may partly have research-tutored aspects, if a group of students is working on a subject and discussing the state of the art.
Our experience is that students learn most by participating (research-based). However, this cannot be done without an introductory course on problem analysis, desk research, research methods and reasoning to come to conclusions. At any case, the active part should be coached to apply the theoretical knowledge in practice.

Student projects are always supervised by an experienced researcher. Students can contribute to several activities in safety research:

- Problem exploration: desk research, interviews, exploring the state of the art.
- Building instruments for research: software tools, information analysis, test tools, experimental set ups.
- Sensor data storage and retrieval.
- Visualisation: making data clear for a better understanding of the situation.
- Experiment execution or simulation of risky situations.
- Observation of real life potentially risky situations.

An elaborate discussion on the student contribution to research within Safety at Work can be found in Van Leeuwen (2012).
7. Concluding remarks

*Ynze van Houten*

This document provides the methodological background for research that is executed in the Safety at Work project. We described a general experimental approach for reliably measuring the effect of any intervention that is introduced to the work floor by applying a sound and valid methodology. We described the methodology specific to the different domains within the project: personal protection equipment, situational awareness methods, and persuasive technology. For each domain, we provided methods for designing interventions and methods for evaluating these interventions in the context of the Safety at Work project. Specific to the project is the educational context, hence the involvement of students in the execution of the research.
8. References


