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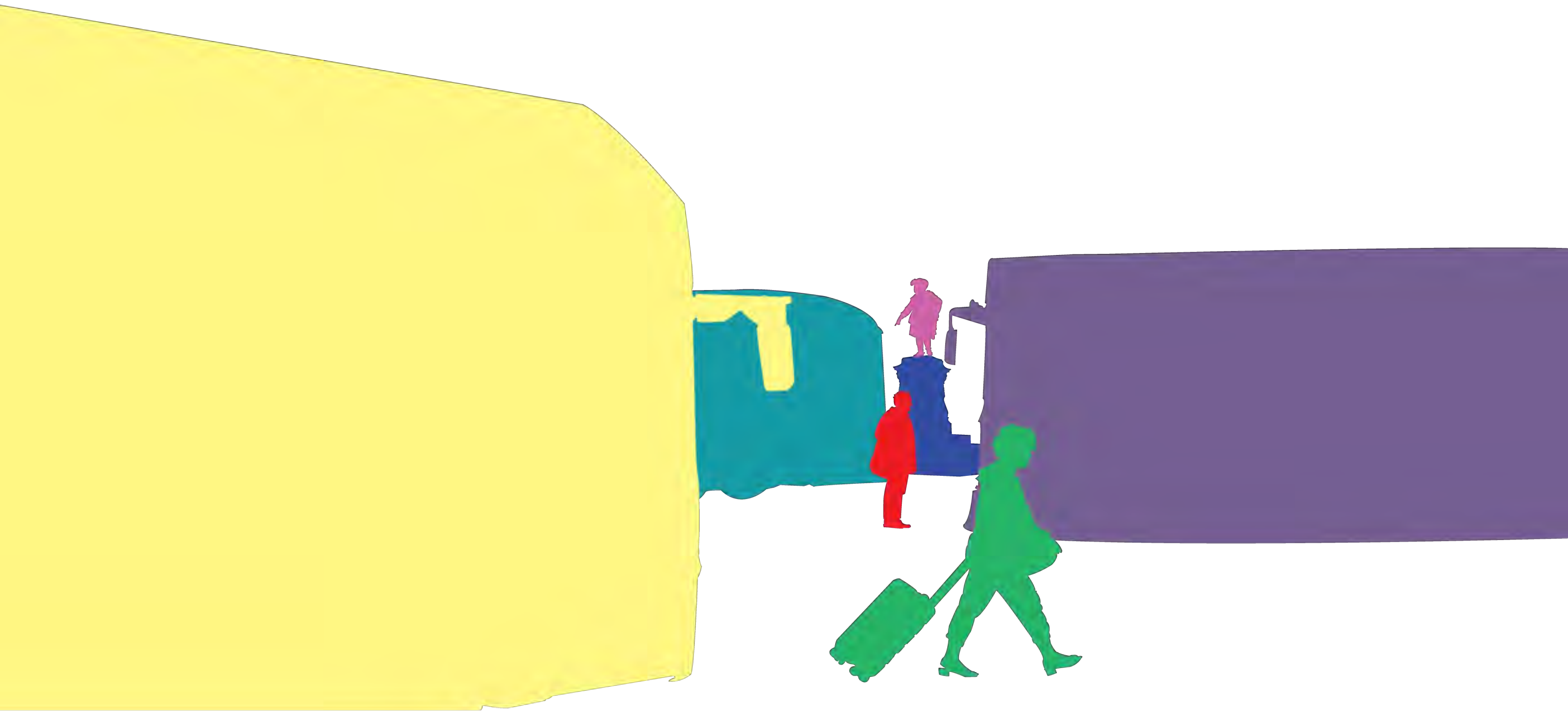

Exterior Warning Signals for Silent Buses

Master Thesis in Interaction Design Technology

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Abstract

Electrical buses are manufactured in order to address issues with the global environment. The silent propulsion of electrical buses can be seen as a positive side effect as noise in the urban environment is reduced. However, concerns are raised as the silent buses may be harder to detect for a VRU, abbreviated Vulnerable Road User. This concern is addressed in pending legislation, pushing for technical solutions such as AVAS (Acoustical Vehicle Alerting System), which proposes addition of artificial sounds. We state questions of how warning signals could be designed in order to maintain effectiveness and comfortability, how well legislation requirements are met, and finally, a investigation of multi-modality.

The warning signals to be designed are partly forced by pending legislation and partly desired from Volvo Buses, which give rise to potential shifts in priority and desired outcome. Action design research suits the change in scope that our efforts induced in the project, through conducting the project. The action design research suits a iterative design cycle in which each iteration results in prototypes that are evaluated provided a context in which it should operate within.

The design perspective used in this project are inclusive and human centred design. The problem of detection isn't a novelty for many user groups in our society, why inclusive design was utilised. The use of human centred design is complementing the vast technical knowledge within Volvo Buses and provides an alternative perspective more suitable to subjective measurement.

The design process includes four iterations, where each iteration has a divergence, transformation and convergence part. Meeting numerous experts, interviewees and users resulted in the Use Cases and User Scenarios. By identifying common patterns a model for warning signal design was formulated. The concepts were designed through a series of creative sessions and a workshop. Photography and video recording was used extensively in order to provide context and inspiration for design.

The results consists of a designed Pattern-Event-Pattern (PEP) model for design of warning signals. The model consists of a pattern and events which can be utilised for designing warning signals that are effective and comfortable. The model is used to generate four design concepts: Eco, Care, Express and EWAS. The latter stands for Exterior Warning and Attention Signal and includes user evaluated audio warning signals. All concepts are described in respective video prototypes. Using multi-modality might be beneficial but remains to be tested. A comparison of visual and audio signals shows that the audio signals are dominant in respect to the visual signals. The dominance of audio signals is inherited as only secondary information can be found through the visual input.

Our finding is that it's possible to design warning signals that receives high arousal and acceptable comfort in a Self Assessment Mannequin-scale evaluation. As the SAM-scale evaluation provided context through a video prototype, due to time and ethical constraints, it remains to evaluate the warning signals in a real traffic situation. The suggested audio warning signals are mapped to a urgency rank which enables a coherent experience. The suggestions of audio signals excludes sounds that were superfluous, already given by mechanical movement or dangerous to change.

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Finally, we would like to thank all the participants in our interviews, workshops and user tests. Your valuable input forms the foundation of our work, findings and designs.

Thank you!

Contents

Nomenclature

AVAS Acoustic Vehicle Alerting System

EWAS Exterior Warning and Attention Signal

FSDB The Association of the Swedish Deaf blind

HRF Swedish Association of the Hearing Impaired

NHTSA National Highway Traffic Safety Administration

PEP Pattern-Event-Pattern

QRTV Quiet Road Transport Vehicles

SAM Self Assessment Mannequin

SRF Swedish Association of the Visually Impaired

UNECE United Nations Economic Commission for Europe

VRU Vulnerable Road User

1

Introduction

The drive of environmental improvement, locally as well as globally, has led to a development towards electrical vehicles. This thesis is associated with the Gothenburg city project Electricity, which includes the new bus route 55 from Lindholmen to Johanneberg. The route was opened in June 2015 and its fleet consists of seven hybrid electric buses and three electric buses.

While the low noise levels exerted by the silent electric buses are beneficial to the local environment compared to the traditional internal combustion engine buses, issues may arise concerning the safety for VRUs.

The first issue concerns the lack of audible cues when a electric bus (or hybrid electric bus when driven in electric mode) is approaching, possibly increasing the risk for the VRU. Especially inattentive or visually impaired road users might be unable to detect an approaching electric bus. As a consequence legislation for constant sound emission for silent vehicles has been investigated by EU, USA and Japan since 2009 (Misdariis and Cera, 2013) and are incoming. European proposals for guidelines on measures ensuring the audibility of hybrid and electric vehicles has resolved in Acoustic Vehicle Alerting System (AVAS), that is a sound generating device attached on the vehicle in order to inform VRUs of a incoming vehicle in operation.

The topic of such legislation is the introduction of minimum noise exerted by vehicles (Sandberg et al., 2010). Such noise exertion could be detrimental to the general health of the urban population (Ljungblad and Renhammar, 2013) in the same way noise emitted from combustion engines harm the urban population (Kihlman et al., 2014).

The second issue relates to the interaction between the VRU and the electric bus, why an interaction design perspective is suitable. With the exterior interaction in mind, communication is mediated between the bus driver and VRU through the bus. Hence the bus influences the behaviour of bus drivers and VRU mutually. A common practice in the automotive industries safety systems is to notify the driver about a dangerous situation, while the pedestrians are expected to be aware when they are in traffic. Since the bus have professional drivers a horn in combination with passive noise have sufficed. As the electric bus to large extent lacks passive noise under 18 km/h it's probably harder to detect why the VRUs can't be expected to notice them to the same extent. By designing exterior warning signals for the bus it can be detected easier and allow for richer interaction between the bus driver and the VRUs.

Thus, emphasis can be put on the interaction between the approaching electric bus and the VRU in order to create a safer traffic environment. The interaction between the approaching electric bus and the VRUs is not only important to themselves but also to the local environment, which makes it important to weight passive exposure to noise into the design concept. However, it is important not to forget that the audio warnings is not the only exterior warning signal for these situations. Light signals, movement and haptic[1] signals are other modalities that serve as warnings. Although the audio often outshines the others, it is important not to rule out possible solutions or supplement into the design process.

Manufacturers of electric buses must assume the responsibility to develop both safe and environmentally friendly vehicles while considering future safety issues that may arise as a consequence of new technology. This thesis is an effort to meet this responsibility.

1.1 Research aim and question

The research problem is about designing an exterior warning signal for electrical buses that is effective for VRUs without compromising a sufficiently comfortable surrounding environment. This results in a design challenge to balance between developing an efficient yet comfortable warning signal. By finding a balance between potential modalities and design concepts this will be tested with users as part of the elaboration to produce warning signals based on human preferences. The concepts contains both visual and auditory elements and investigate solutions both inside and outside of the AVAS legislation. The problem area has resulted in one main research question, with two proposed sub-questions.

- How can exterior warning signals for silent buses be designed, in order for them to be effective yet comfortable?
  - Are multi-modal warning signal beneficial in order to increase the level of comfort, effectiveness or both? Which mode is suitable?
  - To which extent does our warning signals fulfil the current legal requirements, the pending legislation and recommended guidelines?

1.1.1 Scope

One final design concept describing how VRUs are being alerted of an approaching silent electric bus are enclosed in this report. The concept will be described by a prototype

[1]These signals are based on physical interaction, relying on the users ability to touch.

that explains when and how such warning signals are issued. The report will also contain an evaluation of how well the non-technical AVAS requirements are fulfilled and if the recommendations were heeded. Since only the evaluation is within the scope we allow for sounds to be designed that violates the AVAS requirements, the reason being two-folded: the requirements are subjective and they are restricting to the creative process.

Requirements

(i) sirens, horns, chimes, bells

(ii) emergency vehicle sounds

(iii) alarm sounds, fire, theft and smoke alarms

(iv) intermittent sounds

Recommendations

(v) melodious sounds

(vi) insect or animal sounds

(vii) any sound that confuses the identification of the vehicle and/or its operation.

An evaluation of how the requirements are fulfilled will be provided.

1.1.2 Limitations

As a human design perspective is used, we are limited to subjective results. This means that further studies are required to verify our results. Budget is very constrained, why all necessary equipment will be borrowed. Software will be used within the free trial periods if those software licences are expensive. Payment for user tests will consist of cinema tickets. The studies only concern Gothenburg due to the availability of electrical buses. Time will not allow for ethnographic studies (Myers, 1999) as gaining rich material would require too much time. We also decided not to study the driver interface. Even though the interaction between bus driver and bus is as important as the interaction between bus and VRU, we focus on the latter. Including the driver interface would require further studies, such as driver ergonomics, legal requirements for operators, and more. The subject being silent electrical buses will exclude hybrid buses as they are more complex due to a flexible behaviour. The results are probably, but not certainly transferable.

2

Background

THE BACKGROUND for this thesis is introduced from a global perspective focusing an societal overview including infrastructure change narrowing down towards a more local perspective looking at the transportation system and the bus platform. The research domain for this thesis is formulated through analysis of the situation at hand through the different stakeholders point of view. As the local situation is a consequence of a solution to the global environment issue, the relation is mapped and compared in relation to the stakeholders interests and some main stakeholders are identified.

2.1 Research domain

The research domain is found through a holistic approach, by studying the original problem - the global environment. In short, the global environment impacts our society, infrastructure, transport system, local environment and at last every individual. The problem associated with silent buses appears in the local environment, spreading down towards every individual or user of the traffic system. Zooming in on the situation where warning signals are issued in figure 2.1.1 shows how exterior warning signals comes from local interaction between the bus driver and the VRU, mediated by the silent vehicle. The interaction between the bus driver and the VRU is observed by, and have impact on, a lot of members in our society. Identifying groups of such members as stakeholders provides a map, or network, of people who are affected by our design.

Legislation is made in effort to protect the all members of our society including the VRUs and the manufacturer of electric vehicles. A difficult task as existing legislation strives to reduce noise in rural areas while pending legislation strives to increase noise in the public transportation system. Both, of course, have the public health in mind but on separate levels - preservation of long term national health and prevention of swift local accidents. In addition, increasing growth in big cities create infrastructure change as erection of buildings strains the traffic systems as the capacity needs to be increased and more people are affected by passive noise. The passive noise is detrimental to the inhabitants of the city while the silent buses potentially risks the security and health of the VRU. The design for coming legislation is crucial from a societal perspective (Misdariis and Cera, 2013). Therefore it is essential for our collaborators at Volvo Buses when designing for now and the future. As exterior signals are to be perceived by all individuals in the urban environment it's important to design for everyone with a inclusive design perspective. Hence, it's our goal to create a design that allows for an enabling and ethical environment (Steinfeld and Maisel, 2012).

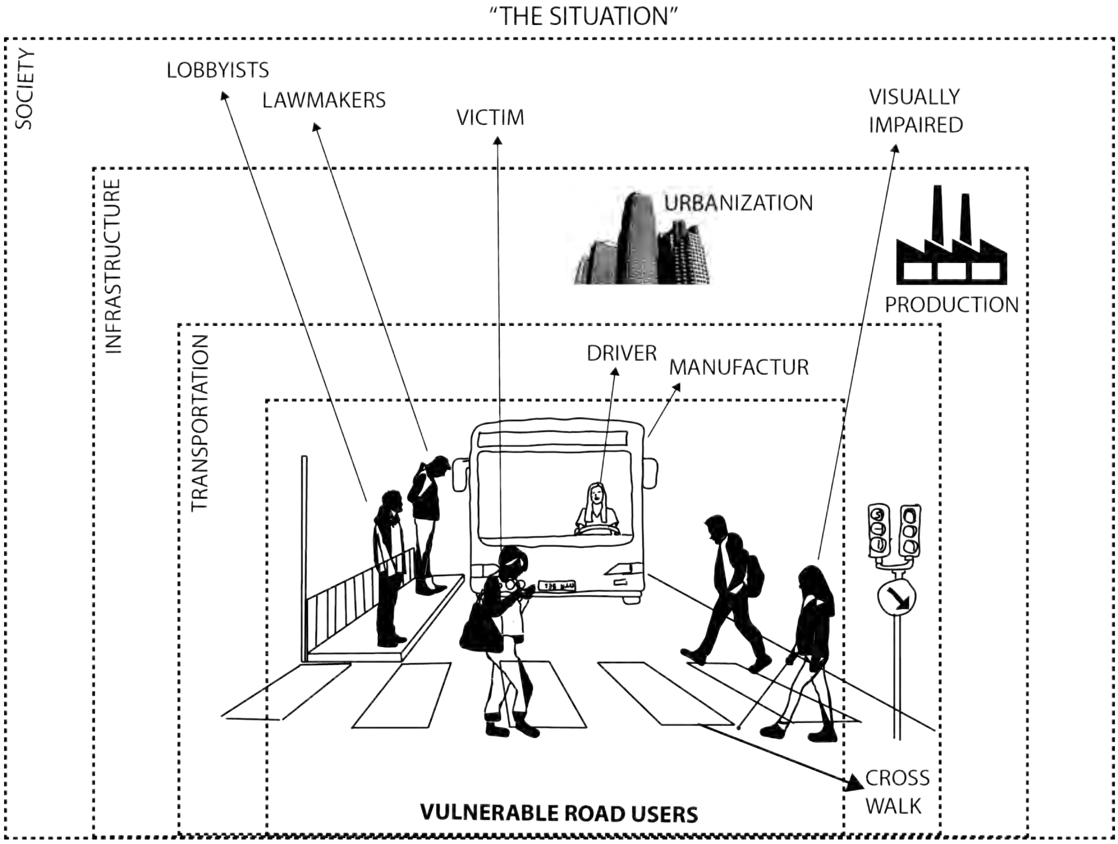


Figure 2.1: Describes the situation from a wider societal perspective towards a more zoomed in perspective focusing on the VRU.

Figure 2.1 illustrate the different involved parts starting on the societal level followed by the infrastructural concerns and changes. The implemented design of warning signals affects the current environment, thus changing the sound infrastructure in cities and landscapes (Misdariis and Cera, 2013). Finally the local level visualised in the core of Figure 2.1 change of roads and transportation system is being expanded to adapt to the new demands.

2.1.1 The local traffic situation

Our local traffic situation derived from the defined global perspective described in 2.1.

A growing issue concerning transportation is the noise generated by buses and larger vehicles. The noise must stay below a certain decibel to meet existing sound requirements, which influence the transportation system to undergo a change toward the more silent electric buses (Ljungblad and Renhammar, 2013). The electric vehicle meets the noise regulations with ease and take part in improved local environment.

To improve the situation, we look at the interaction between the bus, the bus driver and the VRU. By locating the problem down to the bus stop where these parties meet, we can identify the behaviour in traffic regarding this specific situation to be able to analyse and design for this. This is illustrated in the core of Figure 2.1

2.2 Stakeholders

There are a lot of involved stakeholders for the research domain these are quickly described in the later part of this section.

However the core from the local traffic situation described in Figure 2.1 results in the identification of three main stakeholders. These are illustrated in Figure 2.2.

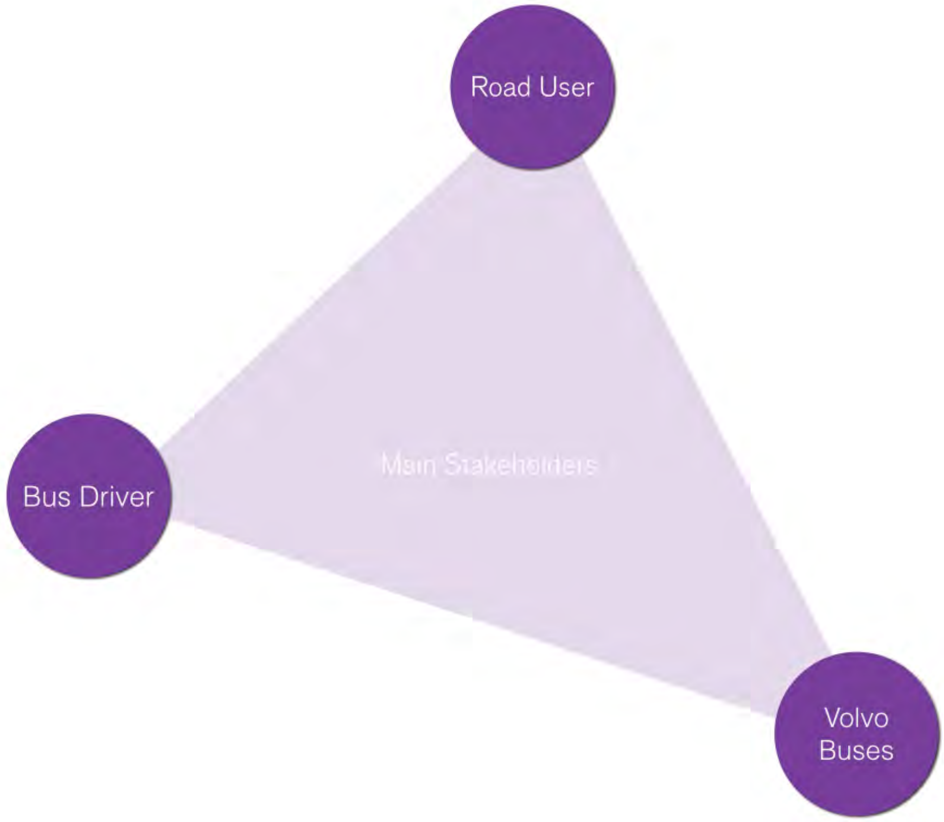


Figure 2.2: Interaction between the three main stakeholders are highlighted.

Both the VRU and the bus driver are directly involved in accidents why the main focus will be on the interaction between them. The bus drivers will to great extent be exposed to any implemented warning system, why their working environment must be considered. Volvo Buses are manufacturers and our employers for this thesis project. Their primary goal is to prevent all traffic accidents involving a Volvo Buses, as well as considering future issues that may arise as a consequence of new technology. Figure 2.3 illustrate all stakeholders accompanying with a list including all the other (and not yet mentioned) stakeholders within our research domain. Moving further away from the core and the main stakeholders from the local level at the bus platforms, the citizens should feel safe in their traffic system and comfortable in their local environment, meaning god design warnings fulfilling it's purpose and at the same time less exposure to loud noises.

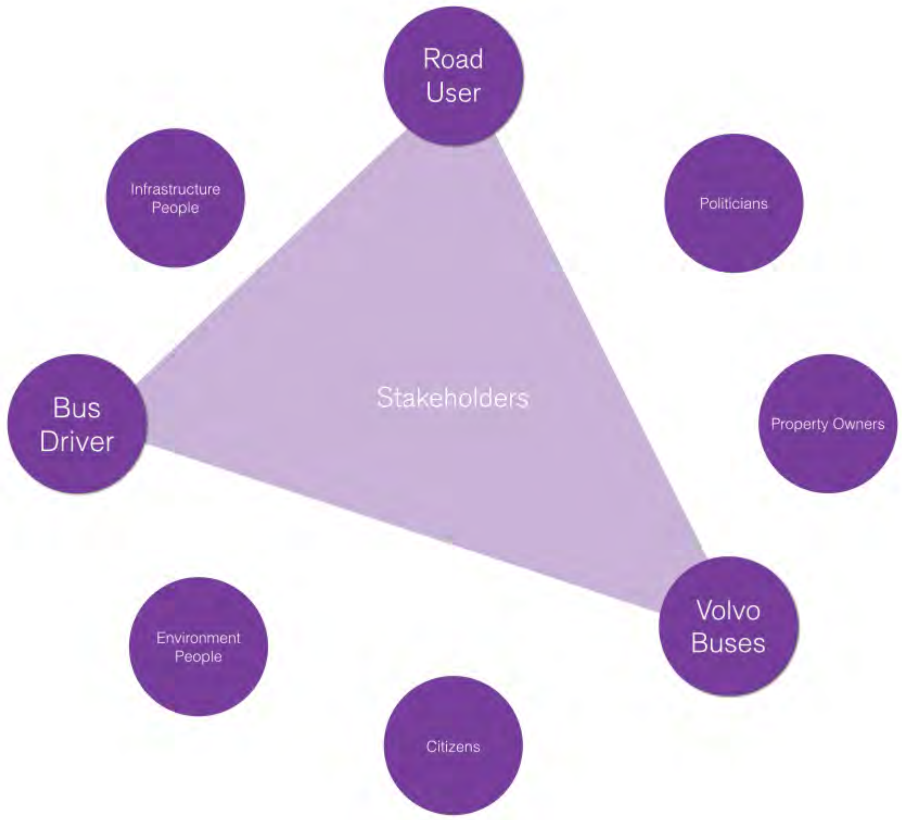


Figure 2.3: An overview of all identified stakeholders and among them the ones who are emphasised in our thesis highlighted by a triangle.

The other stakeholders:

- Politicians - such as lawmakers and lobbyists are involved based on law decisions about noise disturbance in the city.
- Infrastructure representatives - City architects, and city planners could be affected by the design.
- Property owners - Noise in the city might have an impact on estate or property value.
- Landowners - Possibility to erect houses due to change of noise or traffic regulation requirements.
- Citizens - Except the safety of the individuals, accidents and noise in the traffic sector is costly and ultimately impacts the tax payers.
- Environmental representatives - Noise damage gets reduced and general health benefit is expected. Safety issues associated with electric vehicles potentially slows the improvement of the environmental condition.

To sum up Figure illustrate all our identified stakeholders with the main ones highlighted through the triangle.

3

Theory

The chapter of theory is divided into three sections. The first section include the topic of warning signals in general and what qualities that constitutes a warning signal. The second section present legislation, since the highlighted discussion balancing between the major issues and concerns as well whether warning signals are necessary at all. Finally the last section concern interaction design and motivate why and how an interaction design perspective is critical for the topic of exterior warning signals for silent buses.

3.1 Warning signals

Design of warning signals can improve traffic safety as decreased reaction time reduces risky situations. This is bound to both auditory and visually elements with their different advantages. The auditory signal can reach out to more people since they are not bound to one physical viewpoint (Edworthy et al., 1991) within a certain area. The visual signals are less ambiguous as they can communicate complex information in a very quick and concise way. Other modalities might be useful but are unconventional why they aren't discussed further.

3.1.1 Auditory warning

As mentioned in previous section 3.1 the auditory warning signals reach out to more people since they are not dependent on where people are looking. However we have gotten used to the standard warning signals[1] not taking notice to them since they are everywhere around us and has been for a long time (Edworthy et al., 1991). In addition, the signature of the usual auditory signals often is perceived as annoying, to loud, frightening and distracting and therefore often is turned off. Making it important to balance the signals

[1] such as bells, horns, buzzers and sirens

to not under or over designing a situation. Perceived urgency and level of urgency was coined by Edworthy et al. (1995); Hellier and Edworthy (1999) and basically refers to the sound that the listener picks up and the level of urgency it conveys. As a result of this it is possible to adjust the warning signal according to its background noise by giving each warning signals different mapped levels of urgency with an own range within that ranking [2] (Hellier and Edworthy, 1999). This would make it possible to map all warnings, and create a more designed traffic and noise environment. Edworthy et al. (1995) point out that perceived urgency can be seen as a synonym for arousal strength. Both the terms are a result of individual parameter measurement of the overall warning situation and then ranked in order of strength (Edworthy et al., 1991, 1995; Hellier and Edworthy, 1999). Further Patterson (Edworthy et al., 1991; Hellier and Edworthy, 1999) highlights the importance of urgency mapping, arguing that creation of a relationship between the warning signals to be perceived in a set situation are important - making it important to design warning signals synced to each other. Many problems with mismatch of warning signals is described by Patterson as a huge problem in warning signal design. As a remedy, Patterson provides guidelines regarding Warnings speed, Warning fundamental frequency, Repetitions and Harmonic contents. Utilising the idea of synchronization led to three concepts, described in 7.2, which were evaluated as a set of warning signals. In contrast, evaluating each individual warning signal and piecing them together into a concept is done in the EWAS concept, described in section 7.3.

3.1.2 Visual warnings

There are wide variations using visual warning signals. By a quick glance, the VRU can get important information about a situation. Motion can be used to arouse and attract the VRUs attention. Colours can be used to convey different situations or states, for instance - to rate a scale of dangerousness or time or any other situation where this kind of mapping is needed. Furthermore, flash and fade-in and fade-out effects can be used for natural transitions (Edworthy et al., 1995). Perceived urgency can also be used for visual warning signals. Over-warnings, meaning that the warning signal is exaggerated in respect to the risk at hand, are a common occurrence as ubiquitous technology isn't standardised to create a coherent experience in our everyday life. Finding no evidence for over-warnings to be harmful, Edworthy et al. (1995) further means that clutter steals the users attention from warning signals. Another focus discussed is content versus form, as warning signals often are designed regarding how to warn rather than why alerts are issued. Again, the urgency mapping can be utilised in order to distinguish which warning signals are important warnings or just regular messages containing information (Edworthy et al., 1995).

[2]for example it could be the warning signal volume or pitch.

3.2 Legislation

The research of legislation investigates the debate about whether warning signals are necessary at all. It also contains the aim and content of coming, effective or suggested legislation. It highlights the major issues and concerns raised associated with silent vehicles. Up to this date legislation is only at a proposal level in the USA where EU guidelines has resulted in recommendations and restriction through AVAS.

3.2.1 Minimum sound requirements for vehicles

National Highway Traffic Safety Administration (NHTSA), in USA, started created regulations for vehicle noise named "Minimum Sound Requirements for Hybrid and Electric Vehicles[3]" in 2010. This followed in 2011 of a guidelines proposal [4] however up to date no regulations are completed or approved. The regulations emerged as an encouragement from the National Federation for the blind (NFB), which has pushed the issue since 2003[5]. Since electric vehicles are so quiet they potentially endanger VRUs, the United Nations Economic Commission for Europe (UNECE), investigate the Quiet Road Transport Vehicles (QRTV), through creation of devices and recommendation such as previous mentioned AVAS that can be added to the natural emitted sound. The added superficial sound comes from speakers attached to the bus which means that the possibility for any kind of sound signature for the warning system is possible (Allman-Ward et al., 2014). A process to design and deliver optimal sounds for silent cars using AVAS is provided by (Allman-Ward et al., 2014). Both interior and exterior sounds are investigated, though only exterior sounds are relevant for this thesis. Further they created a list of requirements when implementing the exterior sounds as follow in short:

- A good sound for other VRUs moving in traffic. It must be sufficiently enlightening but for the part not annoying.
- Provide VRU with vehicle information, such as location, speed and acceleration.
- It should be a positive sound and strive towards creating a brand value for the manufacturer.
- The design should consider the urban environment.

They emphasize that a combination of all of the recommendations are difficult to achieve. Instead they should be tested and weigh each of these sound recommendations to measure relations and differences of the factors previously mentioned (Allman-Ward et al., 2014). Furthermore, a conventional approach is used when it comes to testing the appropriate sound signal to electric vehicles in the study. They highlight the importance of repeatability when conducting tests. Therefore tests are divided into two main parts consisting

[3] http://www.nhtsa.gov/SampleSoundsandhttp://www.nhtsa.gov/staticfiles/rulemaking/pdf/QuietCar-noi-draft.pdf

[4] http://www.unece.org/fileadmin/DAM/trans/doc/2011/wp29/WP29-153-12e.pdf

[5] https://nfb.org/images/nfb/publications/bm/bm13/bm1303/bm130311.htm

of sound design in a virtual environment and validation in a natural environment. The virtual environment is meant not to be influenced too much by the surrounding factors such as weather, background noise, the drivers driving style and so forth. By using a simulator for a virtual environment a controlled evaluation is being conducted where different sounds can be tested against different realistic scenarios (Allman-Ward et al., 2014). Designed sounds within fixed frames combined with high repeatability made possible for final tests out in a natural environment working as validation of the designs. The sounds were downloaded and attached as add-on speakers on the vehicle with deployed observers in different types of situations.

3.2.2 Critique against legislation

The lack of scientific evidence to support legislation such as AVAS is palpable. Among the major critics it's mentioned that there is no research pointing at the lack of sound on quiet vehicles would lead to accidents (Sandberg et al., 2010). The lack of scientific evidence probably stems from the legislation being proposed pro-actively, taking action as he fear or worry of the problem is very real, as shown by the survey carried out by Wogalter et al. (2002). It remains to see what happens when a increasing number of vehicles in traffic have an electric engine. Even if the need of warning signals is debatable it's clear that there are concerns. As interaction designer it's our job to address these concerns, even if it's not rational. It is also the responsibility of our manufacturers to maintain legal requirements that may come in the form of minimum requirements of sound. The health issues associated with low frequency noise is comparable to the health effects of road traffic accidents, according to Kihlman et al. (2014), criticising AVAS to be a regrettable decision. It might be better for the population in general to get rid of the engine sounds in our society due to heart disease which could be related to exposure of low frequency noise, such as engine noise. Though, a well designed added artificial sound might satisfy the legislation as well as a healthy frequency interval.

3.3 Interaction design

The interaction design perspective focus on putting the user in focus when designing products and services, letting this enhance or improve human interaction Preece et al. (2015). It is about getting to know the user and explore and iterate solutions that makes the user experience better. So in order to draw conclusions about the research problem, the origin of the problem is investigated. Gaining knowledge about the user and identifying needs leads to formulation of requirements in order to design the desired experience. With two of the main stakeholders, namely the VRU and the bus driver, a direct communication exists. Partly, this communication is settled through the use of warning signals. It's a two-way communication that gives expression with the bus as a tool or extension. By creating interaction in form of exterior warnings attached on the bus, VRUs and drivers can be informed in different critical traffic situations and the problem of silent buses in noisy cities can try to be solved. Further the warning signals undergoes several iterations based on the set requirements and need to expand alternative designs. Prototypes can be built to further explore or communicate designs and evaluation of the designs are a supporting decisions made throughout the whole process Preece et al. (2015).

3.3.1 Human emotions response to auditory signals

How we perceive sound depends on many different factors, in an urban environment, there are a variety of sounds that works to overpower each other. How we perceive sound depends on the context in which we find ourselves and what we are doing at that moment. Bergman et al. (2009) conducted research that explains how emotions can influence our perception of sound. There's also a relationship between behaviour, decision-making and elicited emotions. A source of how to conduct tests of emotional response is provided by Bergman et al. (2009) as well, the paper outlines how to measure, test and evaluate sound signatures with human emotions as a factor.

Self Assessment Manikin scale

The Self-Assessment Manikin (SAM) scale uses human emotions as a ranking method for evaluation of different systems or products. The scale measures what the test-participant experiences in terms of given parameters. Through the use of pictorial manikins the three emotion parameters pleasure, arousal and dominance are scored by the test-participant. The test-participant points out the manikin who he or she identifies with the most. The SAM questionnaire illustrated in Figure 3.1 is filled in after the user is familiar with the situation studied.

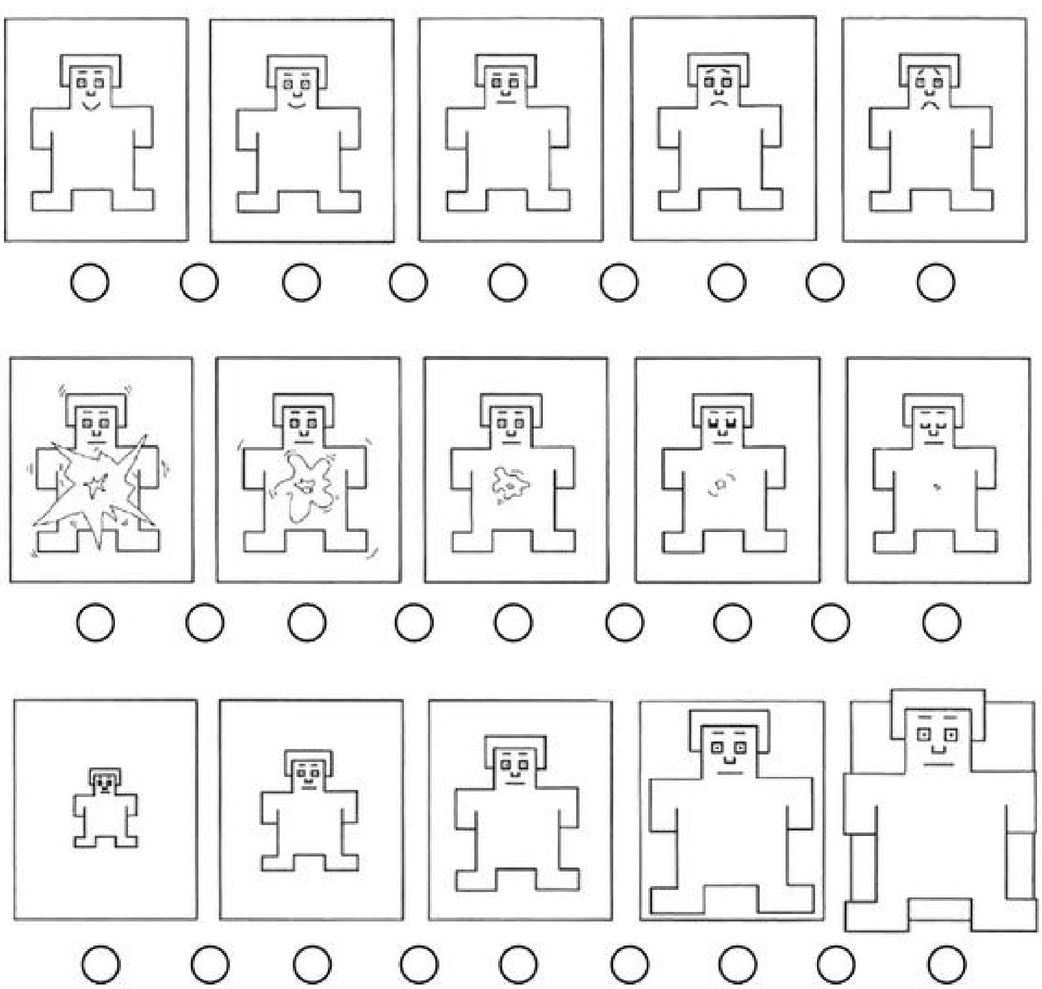


Figure 3.1: The Sam scale used for measuring human emotion of valence (top), arousal (middle) and dominance (bottom).

The SAM scale can be used to estimate the experience of sound. By using the manikins it's easier to describe the parameters as each unit has a graphical representation, a feature is also avoided confusion as the test-participant just points out the answers while the test-conductor notes them. The SAM scale divides in to three different dimensions of core affects, valence, arousal and dominance-submissiveness dimension Bergman et al. (2009). When testing sound the third one (dominance dimension) is abundant and overlapping with the arousal dimension, as sound is typically dominant. The weakness of the SAM-scale is the loss of information as the quantified results can't convey the full range of emotion the test-participant actually experienced. During tests conducted in this study, the valence range in a scale from negative to positive with a neutral position in between. It can be said to be the dimension that controls most of the variation in our emotions. Arousal however, range in a scale of arousal to calm which can be explained by how activated or passive the tested stimuli is interpreted.

4

Research method

The research method reflects how the research is conducted and implies suitable design perspectives. As the result will be qualitative and opinion based, due to limitations listed in section 1.1.2, an opinion based research model is utilised. This allows for methods originated from inclusive and human centred design perspectives,, which is suitable in order to answer the research questions. The research method utilised in this study will be Action Design Research, which is a subcategory of Design Research as well as a combination of Design Based Research and Action Design Research.

4.1 Action research

Action research is conducted through invoking an action into a existing and active environment and then study the ensuing effects. By analysing this effect, another cycle of action can be designed. Such an action cycle is suggested by Wadsworth (1997) in the steps of

1. Plan change
2. Act
3. Observe
4. Reflect
5. Plan a new change
6. Repeat

Another important part of action design research is the focus on what the user does rather than what the user say that he or she does. In design research this is commonly good practice but not necessary, depending on the application. In order to maintain this focus, interviews needs to be semi-structured. It's also important to keep asking the same interview questions to different people. Settling for an answer isn't okay since action research is a process or series of cycles that begin with old action and end with new action incorporating research continuously as feedback from and to action(Wadsworth, 2011). Another potential problem in action research is ethical issue in the sense where the agenda of participators and researchers are in conflict (in contrast to the ethical issues described in the following section). As the common agenda for all participants we've met is to prevent traffic incidents and human suffering, the problem of conflicting agendas is minor.

4.2 Design Based research

Design based research uses the approach of progressive refinement (Collins et al., 2004), which means that a design is put into the real world and then evaluated. In the next iteration the design is refined based on the evaluation and then the design is again put into the real world for evaluation. The cycle repeats until the evaluation is good enough or not improving the design. Explanations for how we follow the guidelines for reporting from Collins et al. (2004) are found below.

- Goals and elements of the design. The goal is to develop a good exterior warning signal for everyone. To achieve this goal we have to look at some critical elements. They all relate to one of our research questions, see section 1.1, which concerns creation of a warning signal that is perceived by every road user through multi-modality. Every VRU should be able to notice the silent bus, but in a manner which do not disturb people moving in the city or living in the neighbourhood. While reaching the goal of the design we intend to follow coming legislation and use suitable modalities.

- Settings where implemented, A detailed description of setting can be found in the design method chapter 5. A walk-trough of how design methods where used and why are included for the reader to evaluate the faithfulness of how the design was carried out in each setting.

- Description of each phase, In the design process 6 every phase of our project is described in detail. Every iteration along with its different evolution are presented. We motivate for every change and describes how critical elements of the redesign better fulfil the main goal.

- Outcomes found, Outcomes found can be in the result chapter7

- Lessons learned, The discussion chapter 8 consider what happened in the different phases, attempting to conclude all the findings into a picture of how the design evolved. Accomplishment and failure are presented as well.

Good documentation is an important factor within design based research to enable researchers to study the results from your work. Further new research projects can build on previous work and draw independent conclusions Collins et al. (2004), why rich material is available in either the appendix or on the homepage.

4.2.1 Action Design research

Action design research can be seen as a hybrid of action research and design research (Järvinen, 2007). Sein et al. (2011) contributes with an literature exploration of the intersection of action research and design based research. They both highlight similarities

Usually science is conducted in order to understand a phenomena by observing it, a common practice is also to avoid intervention while observing the phenomena. The action researcher intends to change the reality through action, usually during the process. The action to induce change is evaluated, which resembles design research - where an artefact is built and tested.

As the artefact is constructed in order to address a specific purpose and the evaluation is of how well the artefact fulfil this purpose (March and Smith, 1995), it resembles the action design. The many similarities are listed by (Järvinen, 2007) in great detail. Given briefly, the action design research is about a utility or artefact that intervenes with the local environment while affecting it and its local users. The process is iterative, includes evaluation and involves users of the utility while the process generates design and domain knowledge.

Our action design research include development and evaluation of the exterior warnings attached to the electric bus located in a traffic environment. Two main issues are addressed, firstly the identification and evaluation of the problem situation and secondly the development and evaluation of an exterior warning that work to support and solve the problem situation. This results in creation and evaluation of exterior warnings to support the user in its context (Sein et al., 2011).

This thesis relies heavily on information from people, some professionals made available through Volvo Buses while other consists of stakeholders, test-participants or associations. Semi-structured interviews are used frequently. A semi-structured interview contains a pre-constructed topic to outline the interview, allowing the interview to be partly open. The open part of the interview is important when getting in to the field as preconceived ideas can result in a poor interview rather than a necessary learning experience.

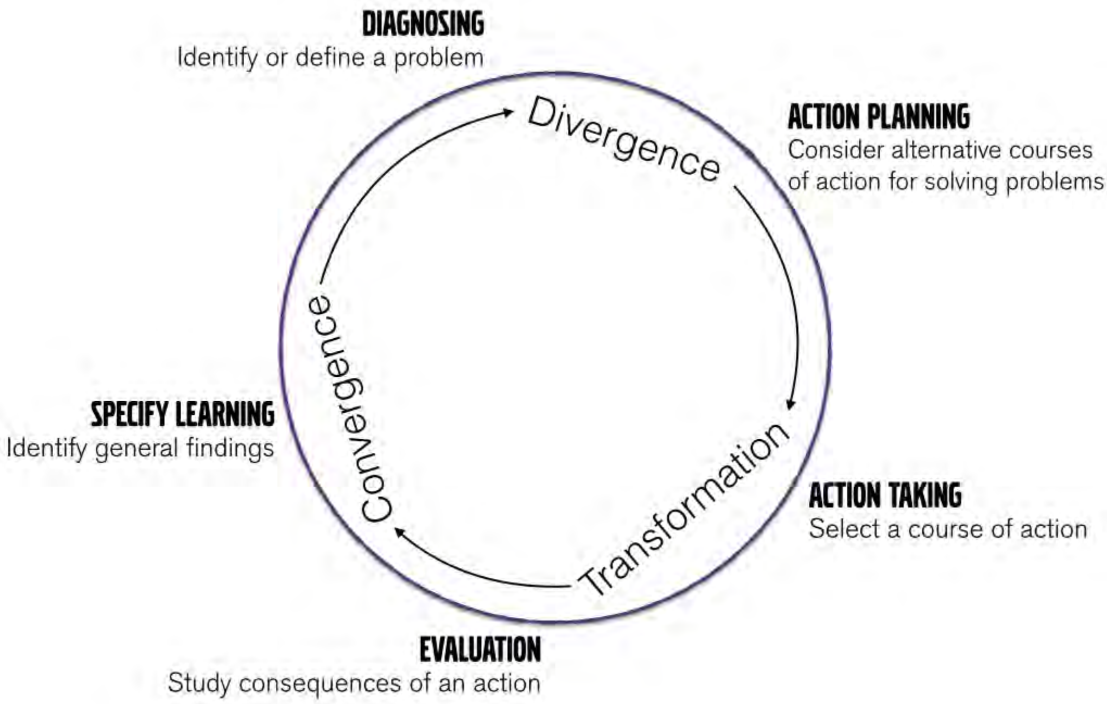


Figure 4.1: The illustration shows the similarity of action research and design based research

4.3 Ethical issues

Consideration regarding participants in our study and their shared data will be undertaken. We will have their consent to videotape, take pictures and other kind of data collection. For video and photography taken in public spaces, we will follow the guidelines of the Swedish Association of Professional Photographers[1]. We will not record, publish or cite any transcripts made available through sign or text interpretation as it is considered a private conversation. Hence we can't use citations from Teleprompter messages sent by interpretors in their effort to allow communication between two people with impaired hearing. Volvo Buses have approved the final version of the thesis. A contract between us, the authors, and Volvo Buses is signed in agreement to which terms that applies, details are enclosed in the contract. Throughout the work an inclusive perspective will be used. Thus, people with disabilities will be included in the set of users and constitutes a valuable resource of knowledge.

[1] http://www.sfoto.se/tio-fragor-om-lag-och-ratt

5

Design method

THE CHAPTER OF DESIGN METHODS describes which chosen design perspectives and methods are utilised. The two perspectives are presented under respective section. The methods are described and motivated in the methods section separately as they don't belong to a specific perspective.

5.0.1 Human centred design

As a phase in the human centred design process, research studies are complemented with methodology for understanding people in their context. Different interview techniques are used to get data which forms a foundation of knowledge. Other specific design techniques and methods are used to extract specific or situation-based knowledge. The gathered input follows is interpreted and synthesised in order to formulate a concise description of the data in the purpose of generating ideas in the form of design solutions or concepts. Finally an adaptation and refinement phase can be utilised to define the concepts (Toolkit, 2008).

During the design process, warning signals are designed in order to address peoples opinions, their environment, as well as the given situation. In order to fully test a warning signal, it needs to be attached to an operating bus with real VRUs perceiving the warning signal. Several technical issues arises, e.g. the location of the speakers emitting the warning signals might give rise to different experiences depending on the receivers position. As the technical aspects are very costly and complex, they are to be tested late in the design phase - which requires the tests conducted early in the design phase to simulate the natural environment to the best extent as possible. Repeatability of the tests is very important in order to minimise bias.

Research within the Design field often mean that tests performed in a natural environment is recommended over tests conducted in a lab environment where loss of natural elements can occur (Allman-Ward et al., 2014). Ambient sounds of a traffic situation must be taken into account, since many warnings may disappear in the crowd. It would be ideal to combine and customise a test situation, while aiming to fulfil an ideally representation of the situation and at the same time include observers with little pre knowledge of the test.

5.0.2 Inclusive design

Inclusive design means that by designing for people with different needs, requirements, wants, disabilities and so forth, we can include every user in our design. (Clarkson, 2003). Not being a novel societal idea, aiming to making life easier for everyone to live in is preferable. For this master thesis this means that everyone should be able to deal with traffic regardless of disability. It is society's responsibility to equip its members with the means necessary to be functional. Assuming that such means have been invented by people in effort to be functional in the daily life, we aim to use the inclusive design perspective to make such tool available for everyone increasing comfort and functionality for everyone.

By working and talking to audio impaired VRUs who potentially already uses aids, helpful artefacts or designs could be transformed into a warning signal that could be perceived by all VRUs. It's sensible to interview users with visual impairment - as they are in need of a warning signal substituting the now lacking audio signals. VRUs with impairments or diverse functionally might utilise abilities and tools more creatively, why they constitutes a very important source of inspiration, ideas and valuable input. The borders between functionally between VRUs are not exact, as different users often engage in entertainment, communication or other distraction which limits the attention span or completely blocks sensory input. The relation between paying attention and exposure to risk is suggested in the study from (Sangberg, 2012) which shows that a majority of tested participants enter an unsafe situation due to cell-phone usage.

5.1 Methods

Numerous methods are used as they are bread and butter to every designer. We show an excerpt of methods in order to illustrate the most important or for various aspects interesting methods.

5.2 Interviews

As interaction designers, it is vital to go out and meet the people you are designing for, the user. To frame the problem, interviews will be conducted including the stakeholders in the field to gain a varied insight into how the problem is treated as well as the attitudes of different people in different situations (Preece et al., 2015).

Predominant usage of semi-structured interviews allows for extra questions or deepening of a topic if necessary (Preece et al., 2015), rather than sticking to a static script. This type of flexibility is suitable initially in a project to gain understanding of the use and situation leaving space to widen up or narrow down the focus of interest (Preece et al., 2015).

Understanding how people move in traffic, how the warning signals are received today, and what VRUs think about the traffic in the city are important. The inclusive design perspective suggests contacting with visual and hearing impaired users of the traffic system. We are also interested in the drivers opinions, how they acts when a warning is issued and how it is treated. Finally, we want to speak with auditory and visual design experts to contribute technical expertise for the intended design work. This concludes conducting:

- Semi-structured interviews with bus drivers.
- Semi-structured interviews and focus group discussions with representatives of people with different auditory and visual disabilities.
- Semi-structured interviews with Volvo Buses internal expert users within the field of auditory and visual design.

5.3 Field observations

The master thesis include many interviews to gaining lots of information about what issues people identifies in city traffic as well as their suggested solutions for those problems. By complementing interviews with observations we hope to collect a broader collection of data. We aim to include not only the things that people talk about, but also what they do, sometimes unaware that they are doing it (Preece et al., 2015).

Initially we aim to observe bus drivers while in traffic to create an understanding of the profession and role in traffic. The focus is put on the interaction between the driver and VRU. When the VRU is moving around the bus. We also aim to observe entering and leaving the bus to get an understanding of this interaction from the drivers point of view. Moving to the VRU, observations will be conducted from various platforms. Through an unstructured observation a foundation for the design of exterior warnings can be mapped (Preece et al., 2015).

As for all the observations we will conduct, we will try to stay in the background not to impact the study more than necessary.

5.4 Benchmarking through SWOT

An investigation of the warning systems implemented on the market today will be investigated through gathering a technical overview. As the automotive market is far more developed than the bus market, with respect to electrical propulsion the benchmarking will be done in that sector. In order to mend the discrepancy of benchmarking another market a SWOT-analysis will be conducted. The SWOT-analysis will address the coming legislation and AVAS-compatibility.

As SWOT analysis can be a good basis for explore existing technology in electric vehicles. By defining the strengths, weaknesses, opportunities and threats a business can map their strategic position and compare itself to other.

5.5 Personas

In order to handle and gather information concerning a project, a fictive person can be constructed in order to represent a group of users who are similar yet slightly different. Personas are composite archetypes based on behaviour patterns uncovered during the course of our research (Cooper, 2014). A persona can then be used to ease communication, for storytelling see 5.6 and more. One of the main features of personas is the ability to focus on the need of one represented group at the time, instead of fitting all the users needs into the design.

5.6 User scenarios

A user scenario is a narrative telling a story. The story is usually about interaction between stakeholders or between stakeholders and the object to be designed. The story is formulated in the perspective of 5.5, a stakeholder or the user. Scenarios are generally written at the beginning of a project during discovery and requirements gathering phases Schaeffer (2011).

5.7 Use cases

Use cases are often written in the form of an actor or user performing an action followed by the expected system response and alternative outcomes Schaeffer (2011). The use cases are written short and compact since they only contain functional information. An example is provided in chapter 6.

5.8 Six Thinking Hats

The Six Thinking Hats is a design method used for expanding or validating ideas and diverge way of thinking. By using role playing and several pre defined roles the method can contribute with creating a valuable discussion with successful problem solving (Löwgren, 2004). The thought is that every participant has a given colour with accompanying role. One advantage is that the method is flexible in the sense that all people can have different roles but everyone can also enter the same role to discuss a topic from a certain angle. One can reflect and discuss different ideas and designs to gain greater insight from different roles (Löwgren, 2004).

White: Moderator	**Blue: Thinking about thinking**
What do we know?	What is being learned?
What do we need to know?	What is next?
How do we get this information?	How do we move on?
Red: Expressing emotions	**Green: Being creative**
What are my gut feeling?	New opportunities?
No need to justify anything	How can it be improved?
Yellow: Being optimistic	**Black: Judging**
What are the strengths?	What are the weaknesses?
What are the opportunities?	What are the difficulties?

Table 5.1: A summary of the six roles included in The Six Thinking Hats method.

5.9 Sketching

Sketching is described by Carpendale (2012) as a fundamental tool that helps designers express, develop and communicate design ideas. Sketching can be used to create and document ideas in a creative way. By putting down the design on paper, deliberation of solutions can be achieved and ideas can easy be communicated to employees and stakeholders.

5.10 Prototyping

The creation of prototypes can be used early in the design process. There are different degrees of prototypes and as an introductory part, rapid prototypes created by pen and paper can be used to communicate a design. The idea is that this kind of Low-fi prototype can be used for testing and evaluation of the design, making improvements and then test again. It is a iterative process that does not stop until the time runs out, or a desired result is achieved. In summary, the result improves the more iterations given. In the later stage of the design process a High-fi prototype can be created as a final presentation of the concept (Preece et al., 2015). This could result in video prototypes, physical prototypes with technical implementation or a web page.

6

The design process

THE DESIGN PROCESS introduces through the time plan given for this master thesis. In the second section the initiation phase is described followed the research phase, the design phase and the documentation phase.

6.1 Time plan

The work were planned to be carried out between the 31st of March to the 18th of August. A coarse plan describing the whole time period is given in 6.1. The time plan is then divided into an initiation 6.2 followed by three phases and at last the thesis work is concluded by the finalisation. Phase I found in 6.3 gives an introduction to the field through literature studies and research methods. A more detailed day-to-day plan of Phase II is given in 6.4, since Phase II consists of the design process. Phase III given in (6.5) will mainly be about documentation, the report you're currently reading and preparation for presentations.

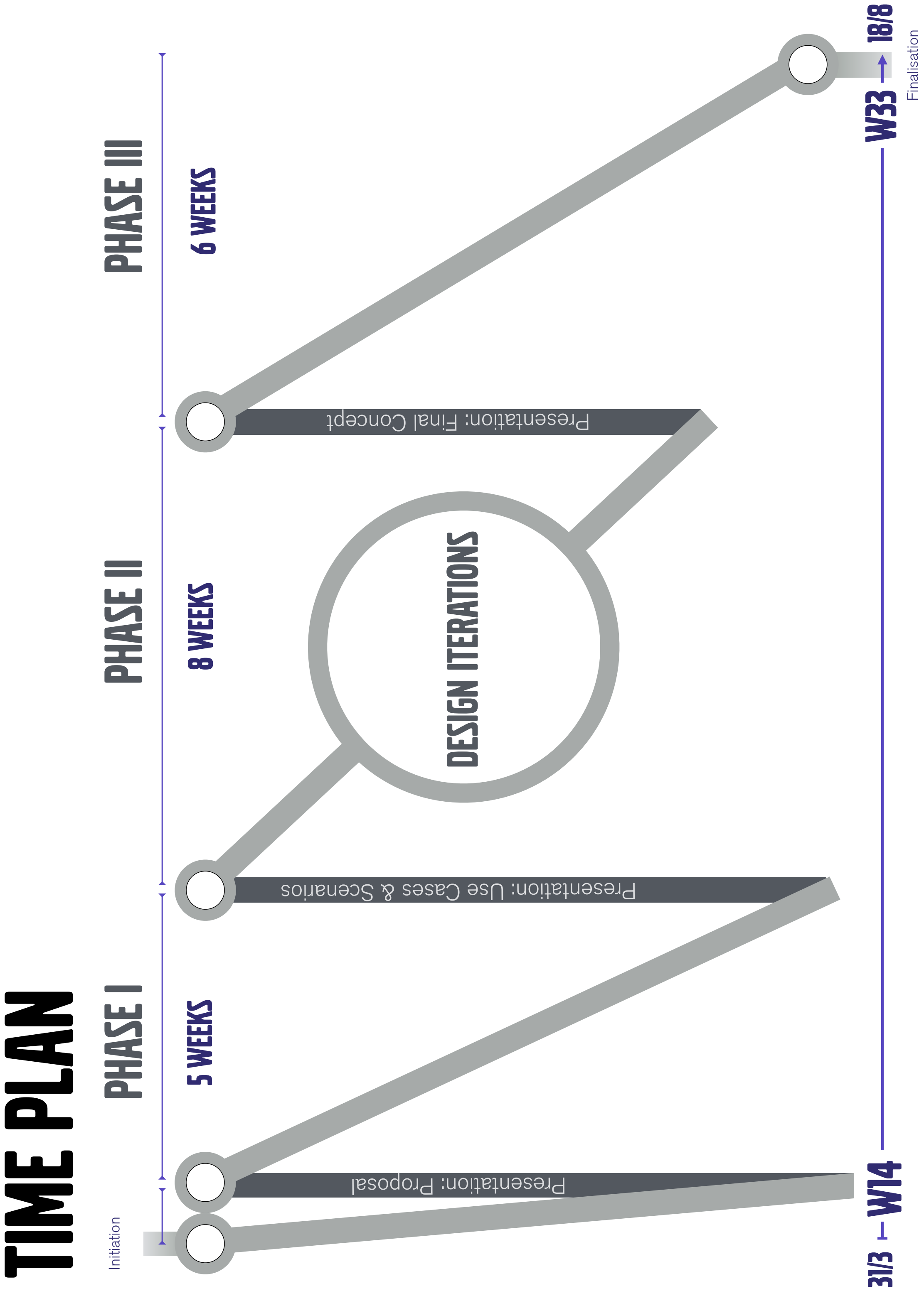


Figure 6.1: The time plan in short. The vertical lines indicate meetings and presentations with representatives at Volvo Buses.

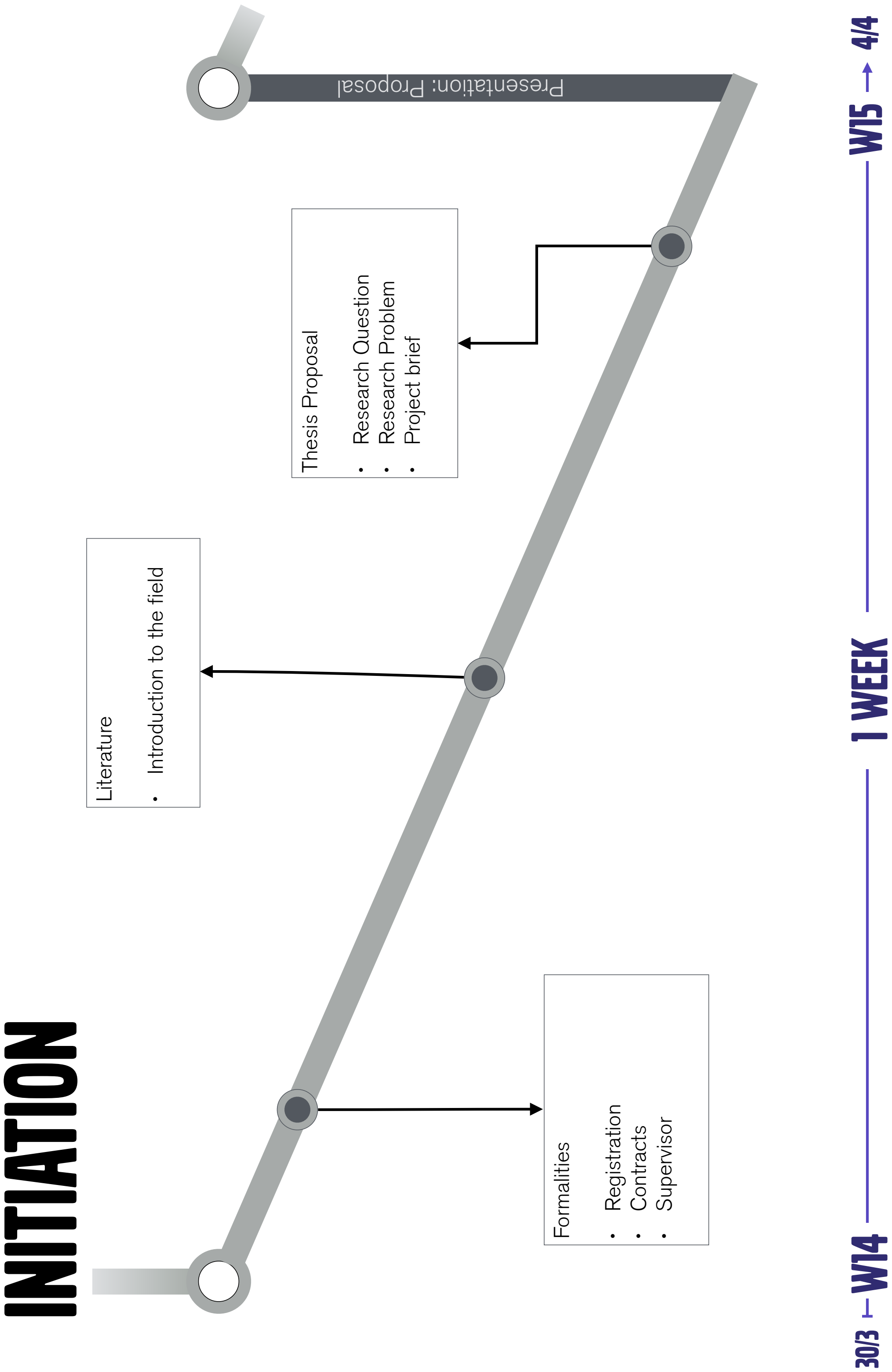


Figure 6.2: The time plan in short. The vertical lines indicate meetings and presentations with representatives at Volvo Buses.

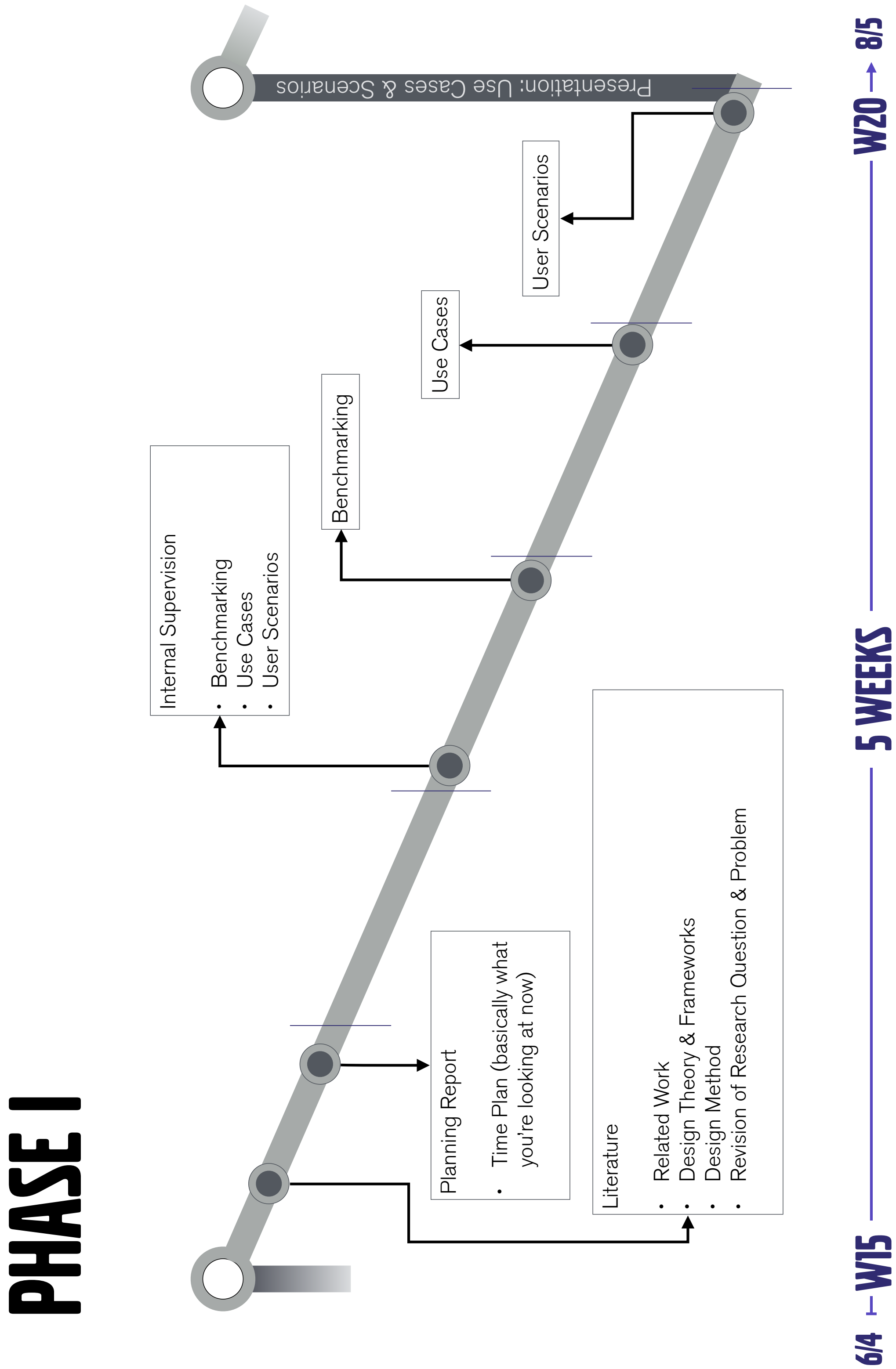


Figure 6.3: The time plan in short. The vertical lines indicate meetings and presentations with representatives at Volvo Buses.

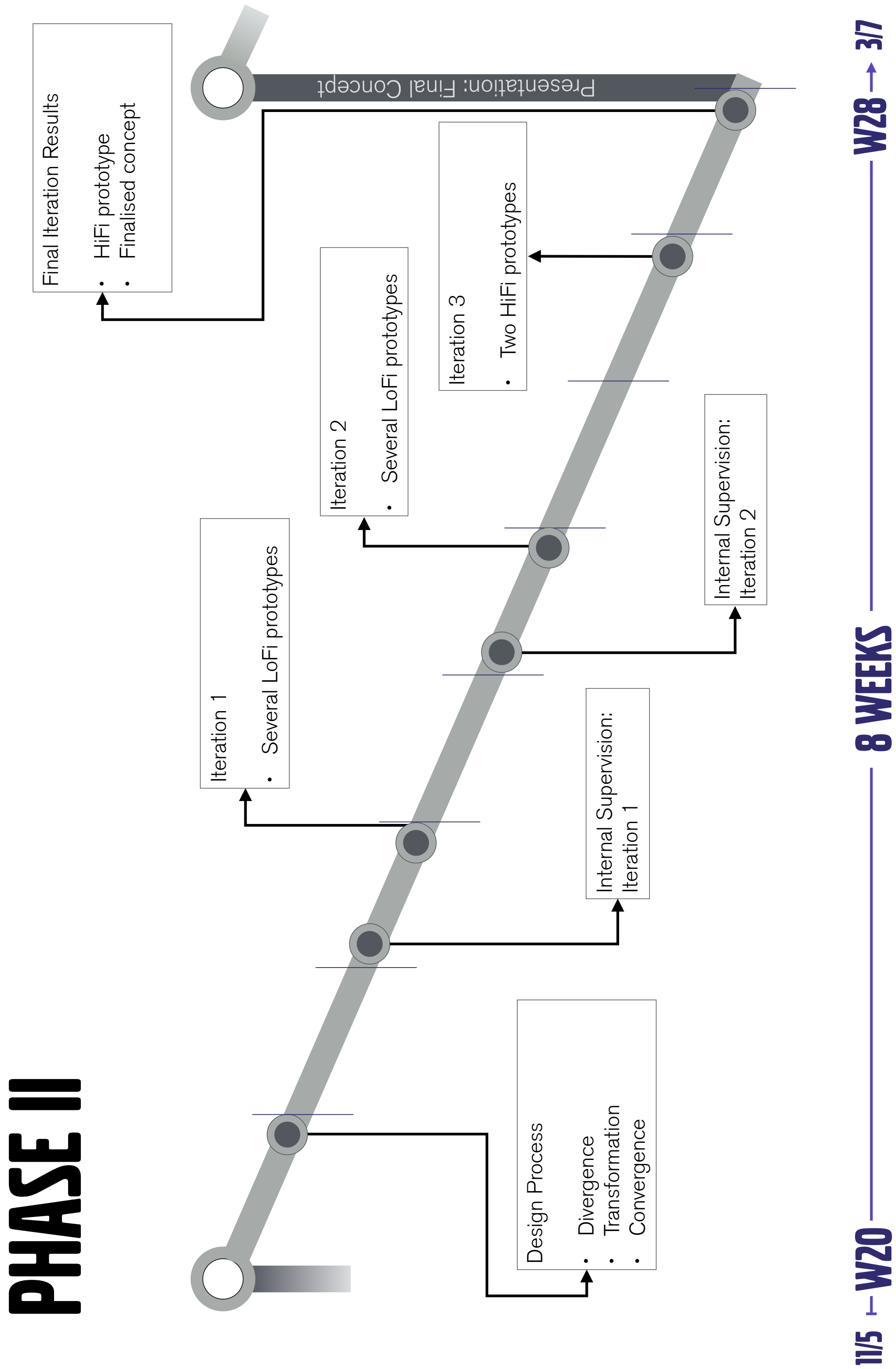


Figure 6.4: The time plan in short. The vertical lines indicate meetings and presentations with representatives at Volvo Buses.

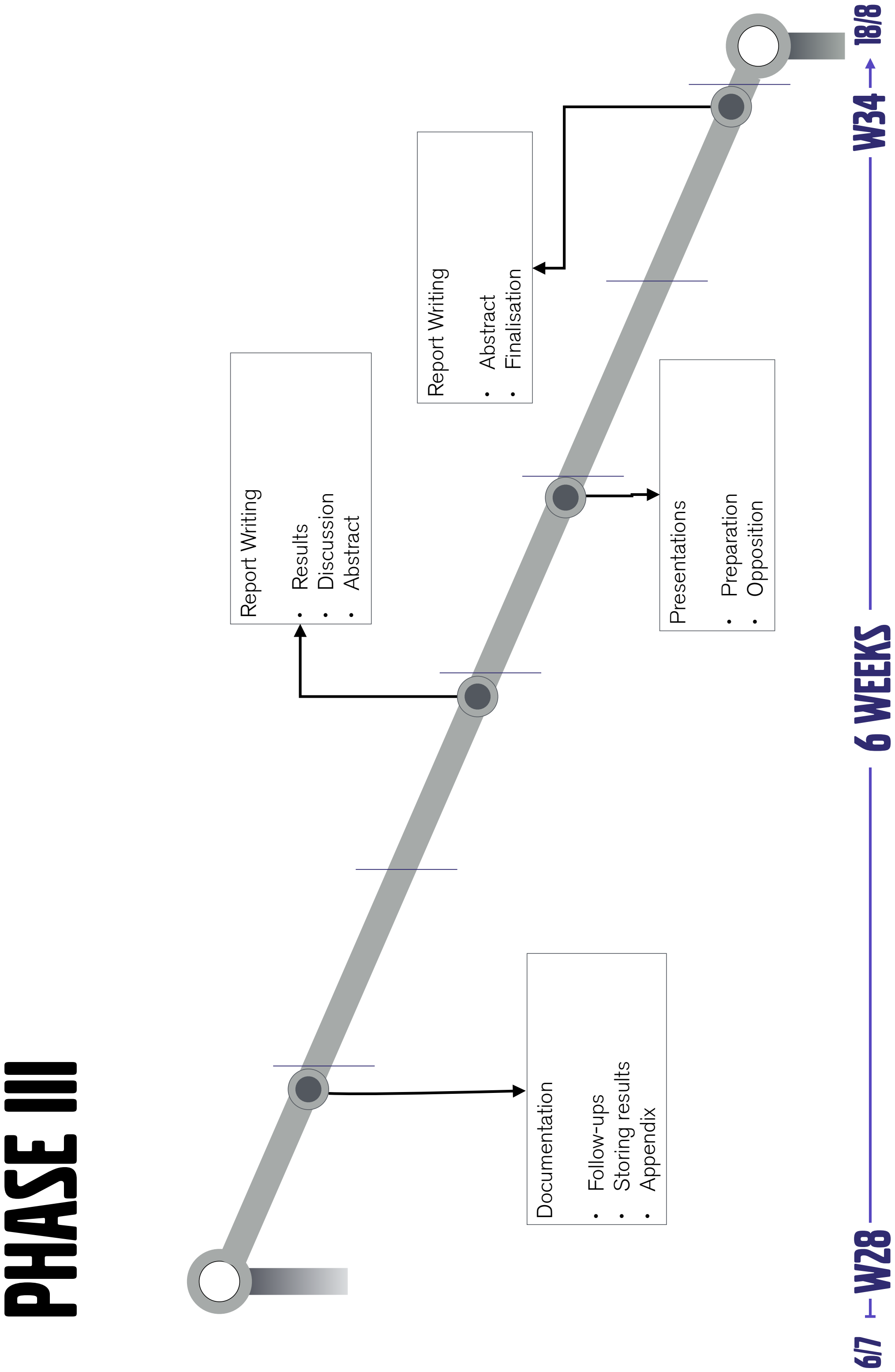


Figure 6.5: The time plan in short. The vertical lines indicate meetings and presentations with representatives at Volvo Buses.

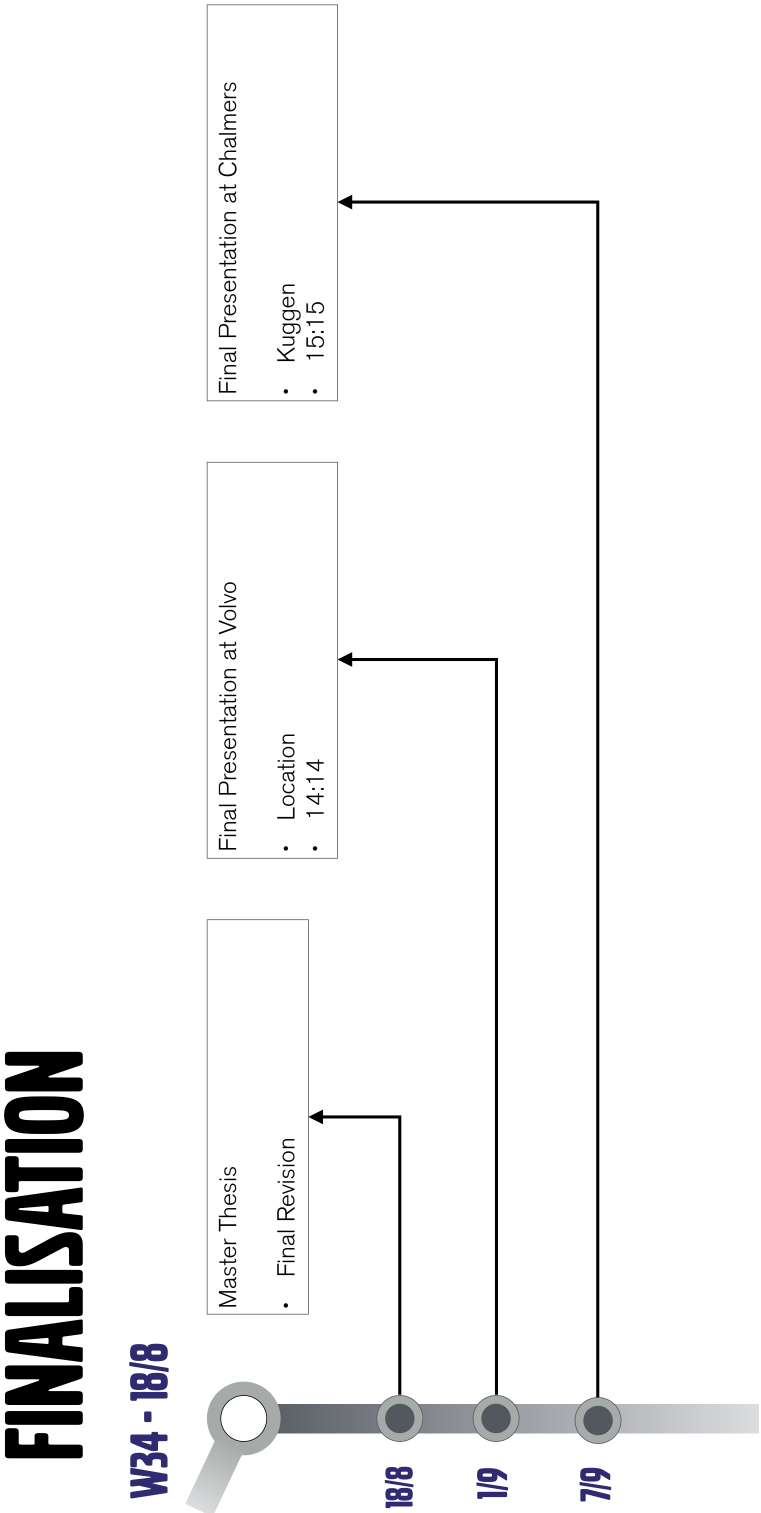


Figure 6.6: The time plan in short. The vertical lines indicate meetings and presentations with representatives at Volvo Buses.

6.2 Initiation

The initiation consists of formalities, an introduction to the field by literature and the writing of the Thesis Proposal. The initiation is concluded by presenting the proposal at Volvo Buses where our company supervisor is inviting people who may be concerned with the topic or are working within the field already. Already in the beginning of the master work, we decided together with our supervisors at Volvo Buses to keep regularly monthly based presentations for interested and involved parties, and between the sessions have unofficial supervision meetings. The regular contact with the company gave a constant design iteration toward improving our performance against what they wanted and expected from us.

6.3 Phase I - The research phase

The research phase is about approaching the problem from multiple angles and to get to know the users and stakeholders. This phase was driven by availability, i.e. identifying and prioritising stakeholders was possible to do from the start. Since there is a market for private electric cars, their warning signals was benchmarked. Silent buses are rarer but alternative technology that's silent as well are more common, trolleybuses for instance. By doing the benchmark we had some ideas about what was conventionally used. Shifting focus towards the users it was clear that the bus has two very different users - the bus driver and the passenger. Starting with the driver, interviews were conducted. As the drivers included in the Electricity project received training to drive the new electric buses, we got the opportunity to talk to them in a safe manner while in the right element. The interviews resulted in very much information about the vulnerable road users and passengers. In order to see the public transportation system from their point of view we decided to do field studies, it would also support the writing of use cases and user scenarios. With all this information we were able to construct personas, which concluded the research phase.

6.3.1 Defining the stakeholders

We needed to identify the parties involved. This was carried out by defining all the stakeholders (described in 2.2). In connection to the development of stakeholders, we were able to create an overall picture of the situation (explained in 2.1) and the environment which in these actors operate. First and foremost, it's about people's behaviour in the common space, but also about public transport and infrastructure relating to it. With this conclusion stakeholders were identified and a problem domain for the research problem was defined. We landed on a local level, where the meeting between the VRU and the electric bus took place, namely the platform. With a narrower focus, we could now go ahead and formulate the research problem and question (defined in 1.1).

6.3.2 Conducting a benchmarking

With an initial knowledge base on the topic, a benchmarking carried out to find out what was already on the market. Electric buses in traffic is a fairly new topic, tests and analyses on the subject are few. In order to get a reasonably accurate picture of the situation we chose to include electric cars in the benchmark. A SWOT[1] analysis was used for the benchmarking process.

SWOT analysis

A general illustration is presented in Figure 6.7 which was used as a basic evaluation where we went through a list of several electric vehicles to then write down all of the weaknesses, strengths, threats and opportunities that we could identify. How we collected the results are represented in Figure 6.8. The size of each box is dependent on amount of identified strengths, weaknesses, opportunities and threats.

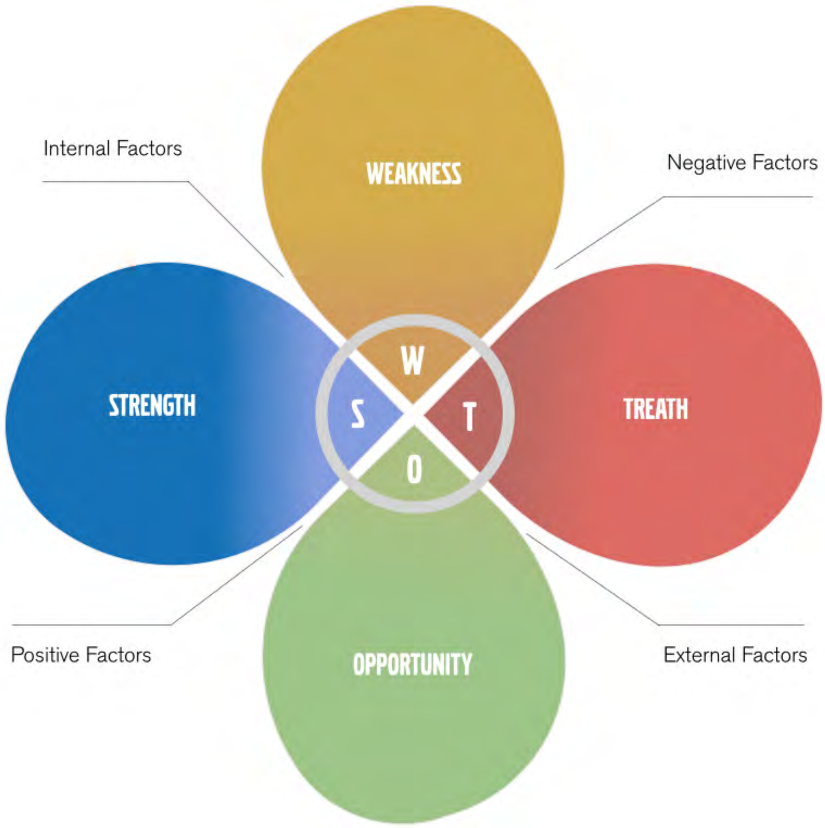


Figure 6.7: A general SWOT analysis in relationship to internal, external, positive and negative factors.

[1]SWOT is an acronym based on the English words Strengths, Weaknesses, Opportunities and Threats

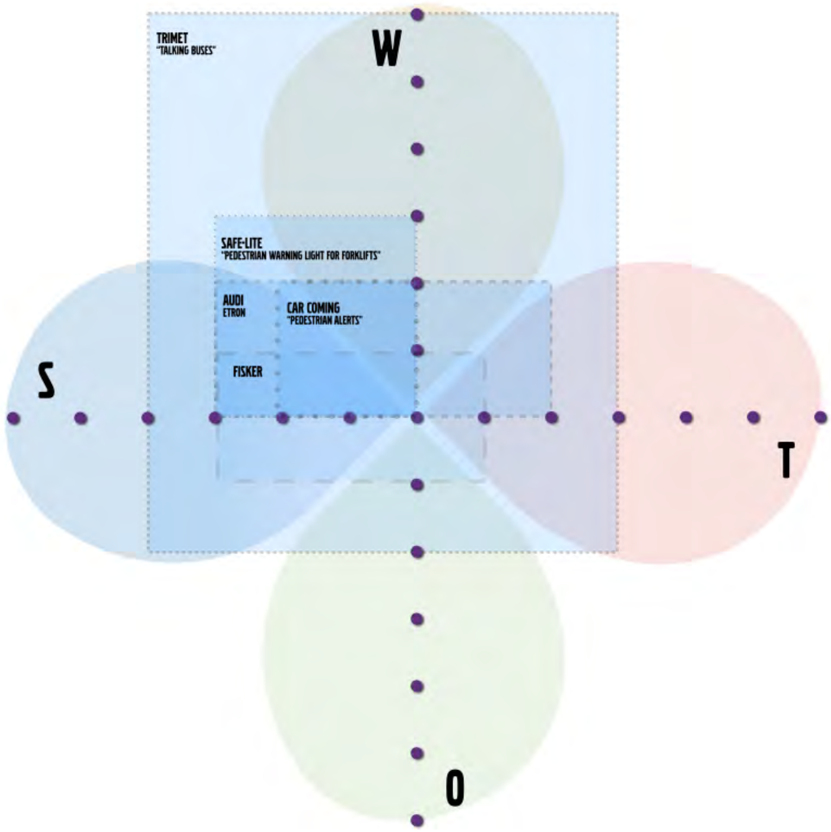


Figure 6.8: A selection of benchmarked electric vehicles in a SWOT analysis.

The main purpose of using a SWOT analysis was to create a domain knowledge in the field of silent vehicles and at the same time get our own preferences in the subject as this at the time was lacking.

6.3.3 Personas

Personas were created (read about what a persona is in 5.5) to define the target audience in an environment where such a mixed crowd moves resulted in a very abundance regarding potential VRUs. However inclusive design was supported by carefully review conceivable less common cases. This lead us to take initial contact with various organizations that work to promote various types of disability in everyday life situations. Figure 6.9, 6.10 and 6.11 illustrate the three personas created and used during the first two weeks of the project.

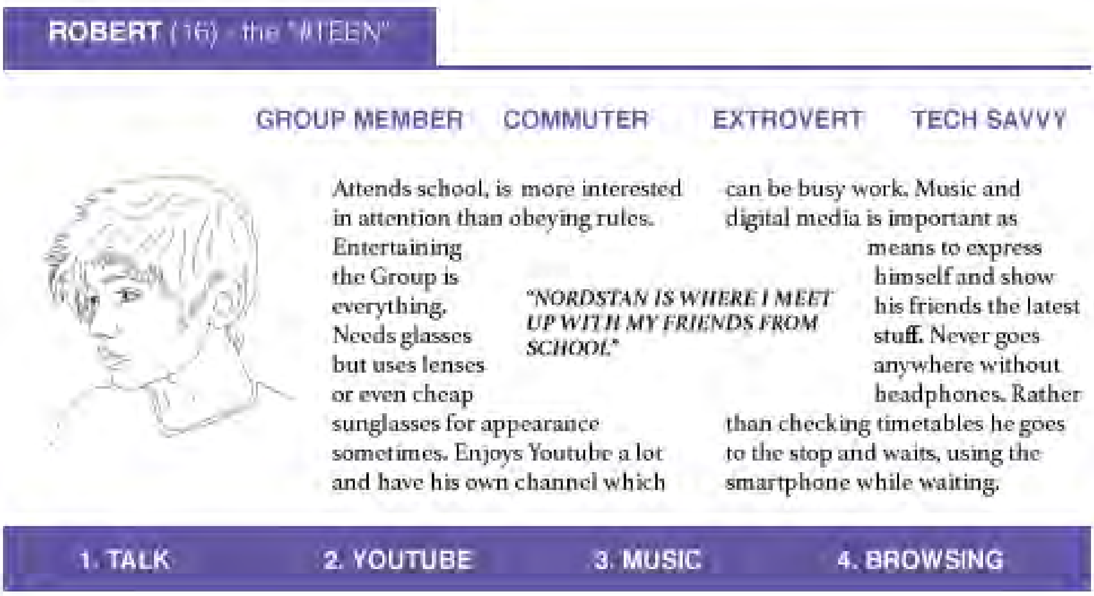


Figure 6.9: Persona 01.

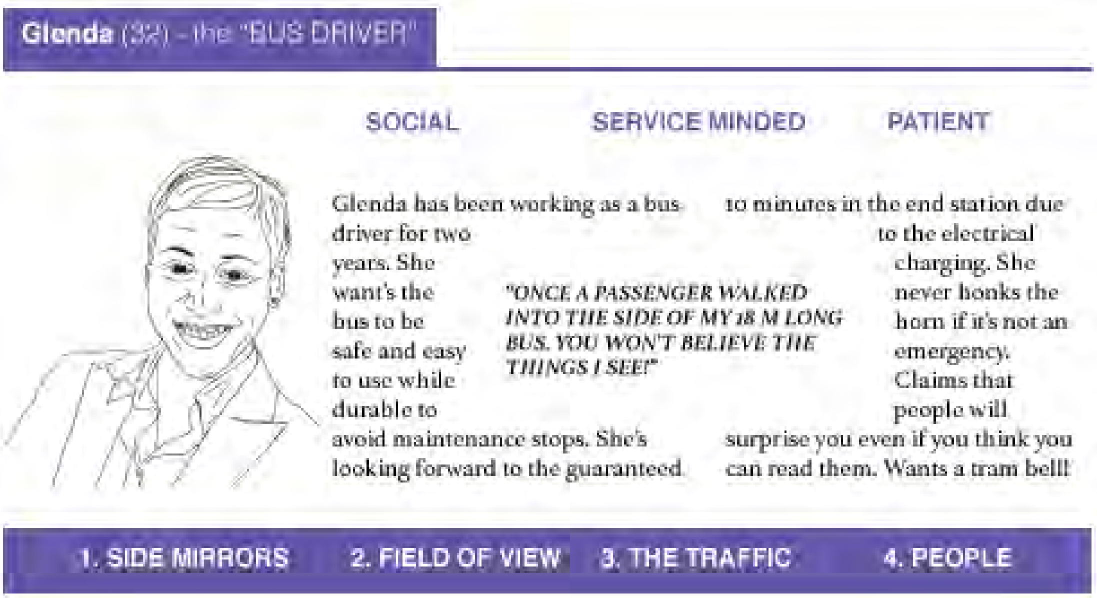


Figure 6.10: Persona 02.

Figure 6.11: Persona 03.

The earlier benchmarking and the personas were discussed at a Volvo Buses presentation. The benefit of easier communication wouldn't really be helpful to us since the pair of us can discuss different uses quite easily anyway, due to good communication. We also serve a huge user group in this project where the personas lack effectiveness to include them all into the design. Therefore the personas were dismissed and user scenarios and use cases later implemented in its place.

The benchmark provided excellent domain knowledge and some of the ideas could serve as inspiration to buses, however - the absolute majority of external warning signals are associated with electrical cars, not buses.

6.3.4 Interviews

Early interviews and observations carried out as a result of close supervision with our Volvo Buses representatives. This was in form of an opportunity to spend a whole day with Keolis bus drivers as they took part in a educational training of how to drive the new electric bus. We also got the opportunity to meet with auditory and visual experts at Volvo AB.

Bus drivers of electric buses

The interviews with bus drivers took place during an instructional day for aspiring drivers of electric buses. Therefore, the study needed to be flexible so as not to disrupt operations more than necessary. We took advantage of the time and conducted interviews both during, between and after the training sessions. At their disposal, they had a all-electric bus and two electric hybrid buses. Two drivers took turns driving in each bus.

This create an opportunity to interview the non-driver while waiting for his turn. A total of 8 bus drivers were included in the study.

Prepared questions can be found in detail in the appendix as well as transcription of all interviews. The questions asked did not always follow the script due to unstructured environment moving between different buses. New questions where created on the fly and occasionally an interview was interrupted do to time limitations. A summary of the interviews follows below:

- The interviews reveals that the horn is not used in many situations. Drivers often feel like it is too loud and sometimes arouses more attention than necessary, with the result that VRUs are frightened.
- Sometimes you want to enlighten pedestrians of a bus approaching, standing still or just inform about the status of the bus.
- Another common problem that arose was that the side mirrors not being noticed by pedestrians walking too close to the platform while they do not notice the bus's side mirror when the bus arrives. The driver has no good solution to inform pedestrians that they are in the way, walking to close to the platform.
- With a lot of people in front of the bus, it is difficult for the driver to get around. People move in clusters in traffic resulting the driver to wait. The driver wants to signal that "now I want to go."
- Another problem that was observed is vulnerable cyclists. The cyclist is exposed to danger when the bike lane and bus lane merges. The driver wants his intentions to appear better for the cyclist to take better decisions.
- A general impression from our interviews is that drivers think that some VRUs to be careless in traffic and see the bus as a harmless object. (Read more about how we conducted the interviews in 6.3.4.)

By releasing us on and off the bus while in training, the drivers helped us to implement observations of the bus exterior and signals.

People with disabilities in traffic situations

Although we see the silent vehicles as a new incoming problems, this is something that some people in our society have lived with all their lives. The goal was to examine function varied peoples way of travel in city traffic. We wanted to know if they have any traffic aids, or any other comments that could be considered. As our solutions to the problem would also potentially concern visuals on the exterior of the bus, we wanted to reach out to the visually impaired as well. Several interviews where scheduled. We attended meetings with members of Swedish Association of the Hearing Impaired (HRF), representatives from The Association of the Swedish Deaf Blind (FSDB) and Swedish Association of the Visually Impaired (SRF). This contact lead to two interviews and one group discussion. At HRF we were invited to one of their meetings where we got 1 hour disposal to ask questions and sustain a discussion. With FSDB and SRF, we got to meet a representative each to carry qualitative interviews. The first interview was with Berit Jildenhed from FSDB and the second one with Erik Johansson Lönnroth from SRF. The group discussion was at HRF at one of their meetings. Thoughtful design may improve a visually impaired person's environment. A summary from all the interviews follows below:

- Swing doors on the bus allows for easy access compared to pulling up the door yourself however, it is easy to become trapped, which have happened to many of the people we interviewed. It is therefore very important with automatic stop positions on the doors when something is in between.
- Placement of signs and information boards should be placed at eye level. Visually impaired people often see very poorly from afar. Strong and good lighting of signs is also important.
- Light from above is better than a light around the sign or from the front as it can dazzle the sighted. If it is about moving warnings, these should always be supplemented with speech.
- Lighting can help to mark special places and objects that are important, such as information boards, bus stops and doors.
- It is important to work with contrasts in the design work. If the floor and walls are painted in colours with poor contrast, it may be difficult to perceive the size and localisation of the room. Colour combinations are also recommended to avoid since many visually impaired find it difficult to distinguish them from each other.
- Large surfaces is easier to detect, preferably use long and large areas for warning signs or warning lights.

6.3.5 Field observations

In order to figure out what passengers intended we observed them in the field. The observations of the drivers gave us an idea of the profession and what pressure drivers are exposed to in traffic. On several occasions, pedestrians walked out right in front of the bus without looking. We determined that it was time to look into the pedestrians point of view by carry out a city traffic observation at the platforms (read about how we conducted the observation in 5.3). The main priority was to observe ordinary people in their interaction with the bus at and around the platform. By doing this we defined typical situations in which traffic danger was a fact.

Observation of the bus platform took place at various stops around the city, one of the places we spent most of time was at Hjalmar Brantingsplatsen, Hisingen. The stop is built so that buses, trams, pedestrians and cyclists meet each other without any clear structure on the road safety. We also observed at Brunnsparken and Kungsportsplatsen.

The length of the observations varied within the time span of 30 - 60 minutes. After only 10 minutes on the platform several causes where people crossed just in front of a bus which was about to leave the bus stop and possible traffic hazard could occur. The bus driver is often forced to slow down for pedestrians who neither seek eye contact or look around before crossing the road.

Sound evaluation

By contacting Lars-Ola Bligård, a researcher within the design and human factors, Product and Production Development at Chalmers University of Technology, we got the chance to partake in two sound tests he conducted at Volvo Buses behalf. The first test was a test on a electric car with externally mounted speakers. The second test was on a hybrid bus that was taken from service on route 60 for the test. A speaker was stored in the front of the hybrid bus, while a Mobileye[2] was used as a trigger. By uploading the sound through a Raspberry Pi the concealed speaker played the sound whenever the Mobileye detected movement in front of the bus. The sound were evaluated through observation when the bus approached a man-sized mannequin, see 6.12.

Figure 6.12: The sound test, consisting of the mannequin, the bus driver Claes Tornevall and the evaluators from left to right: Ida, Lars-Ola, Kim and Jonas.

[2] http://mobileye.com/en-en/

6.3.6 Expert interviews

To obtain a more technical knowledge about auditory and visual design, our supervisors from Volvo Buses organised meetings with experts in each area internally by Volvo Buses. We got an opportunity to met Dennis Saluäär from Volvo Group Advanced Technology and Research who contributed with visual signal knowledge and presentation of imagined solutions and Pontus Larsson(also one of our main supervisors), Sound designer from Volvo Group Advanced Technology and Research helped us with getting to know Pure Data and introduced us to how to create warning sounds accordingly to frequencies and decibels.

User scenarios

Specific user scenarios were created as a basis for discussion in the workshop session, Figure 6.13 display the collection, however they are available as PDF's here or could be found in the appendix D.1. They describe specific situations found through field observation and interviews with bus drivers and VRUs. The locations included in the study where restricted to:

- Kungsportsplatsen
- Brunnsparken
- Hjalmar Brantingsplatsen

The chosen locations for observations and photography[3] were based on the mentioned interviews but also due to diversity in crowd, VRUs, transportation and location. In D.1 our initial 12 scenarios are described.

[3]The photography was in accordance with 4.3

Figure 6.13: A collection of our 6 user scenarios

Use cases

Having observed and interviewed bus drivers and VRUs at different locations numerous use cases could be identified. In combination with knowledge from our user scenarios and field observations, use cases where identified and two sub categories created, displayed in Figure 6.14.

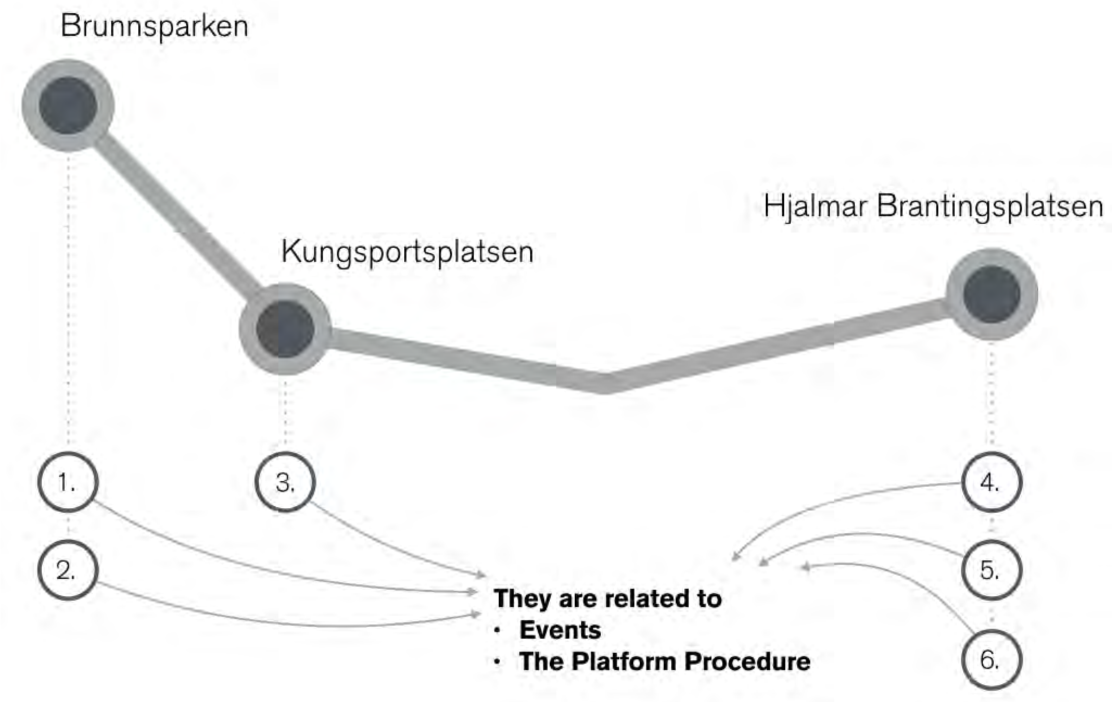


Figure 6.14: Illustrate how use cases arose from user scenarios that emerged from the three main locations studied.

Platform procedures

The platform procedure seen in Figure 6.15, consist of the steps the bus undergo while being on the platform. By highlighting these steps the interaction and design of exterior warning signals can be introduced to specific use cases. The platform procedures is described in detail below:

- Constant: The constant parameter aims at the continuous sound of the electric, silent bus. If a potential legislation comes in, it is a priority to create a continuous sound for the silent buses. The constant sound is supposed to operate in speed below 18km/h bringing attention to the VRU.
- Deceleration: The sound of deceleration is intended to come either as a continuation of the constant sound when the bus arrives at the bus stop as an additional indication and increase of warning to that bus arrives.
- Stop: Indicates that the bus is no longer moving.
- Open: Indication that door is open/opening, short process.

- Close: Indication that door is close/closing, short process.
- Start: Short indication that the bus is about to start moving.
- Acceleration: Similar to deceleration, the sound of acceleration is intended to come either as a continuation of the constant sound when the bus arrives at the bus stop as an additional indication and increase of warning to that bus arrives.

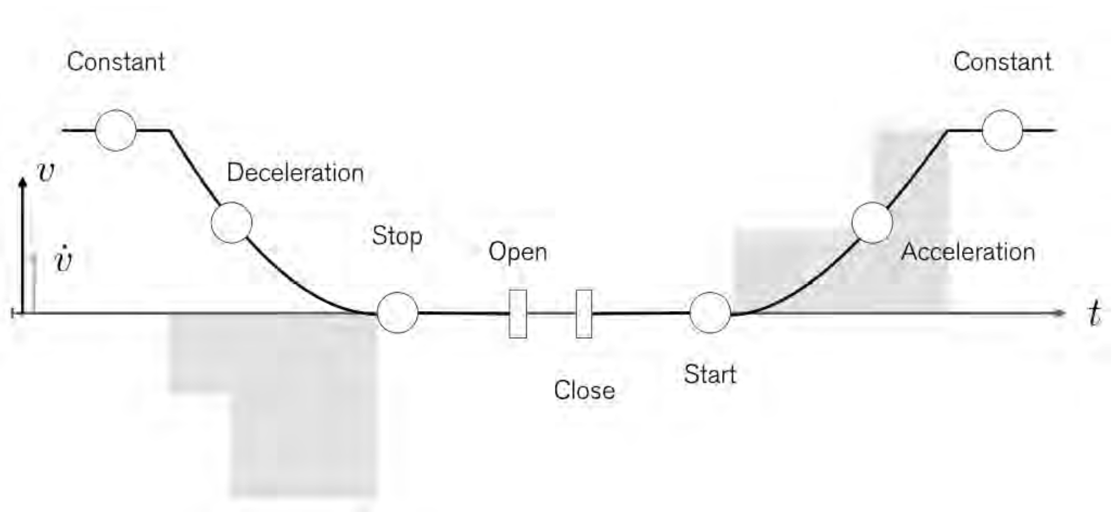


Figure 6.15: Use Case - Platform Procedure

Events

The second category events, origin from uses cases result in three events taking place illustrated in Figure 6.16.

- Danger: In the form of the bus's original horn, this is not likely to be replaced when it comes to security. It is a well known signal that many know.
- Attention: Aim at symbolising a kind honking that you can use to get people's attention in less important situations, such as to get people to notice that they soon will be in the way or for telling them that the bus arrives from behind.
- Arbitrary: The arbitrary signal provide more information to the road user. Users learn a behaviour by spend time in traffic situations and thereby get access to more information when noticing the arbitrary signals. Users who do not understand or want this arbitrary signal will not be disturbed by lot of unnecessary clutter, but will still be warned if needed.

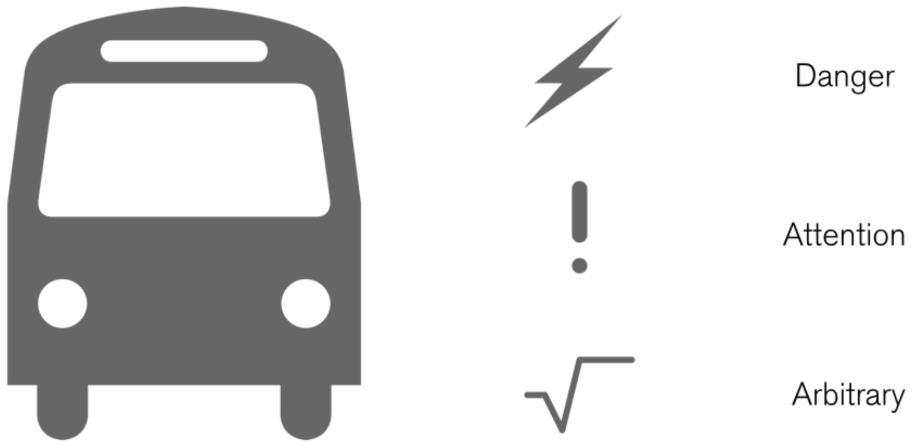


Figure 6.16: Use Case - Events

6.4 Phase II - The design phase

The design phase consists of an iterative process where each iteration contains three parts: divergence, transformation and convergence. While the divergence phase contains idea-generation and new thinking the transformation phase is about improving or combining existing ideas. The convergence phase is about evaluation or testing of ideas, concepts or prototypes. The result from the convergence phase goes straight into the following iteration. This process is repeated until a satisfactory result is obtained.

6.4.1 Iteration 1

The first iteration started with several brainstorming sessions. Sketches was produced of visual warnings illustrated in Figure 6.17, and sounds where identified from audio databases. It became clear that discussion of sounds unrelated to situations was hard, if not pointless. It was also very hard to evaluate sounds. As the environment of public transportation is available for everyone we figured that a workshop could be very rewarding leading the process forward. After all, everyone has insights and opinions about the public transportation. We sent out invites to a workshop where the invitees were designers. We had the opportunity to borrow a directional loud speakers to see the possibilities of this. We also got Little Bits to prototype own audio warning examples.

Divergence

The brainstorming consisted of several sessions. With the help of pen and paper sketched ideas were created and presented in one of the session. These were discussed and developed to new ideas and thoughts. An 1 hour session led to around 30 simple sketches of various design proposals to take forward in the process. The resulted sketches were predominantly of visual warning designs which in the second session lead to brainstorm through a digital sound database to pick out relevant sounds, unrelated to situations but to personas.

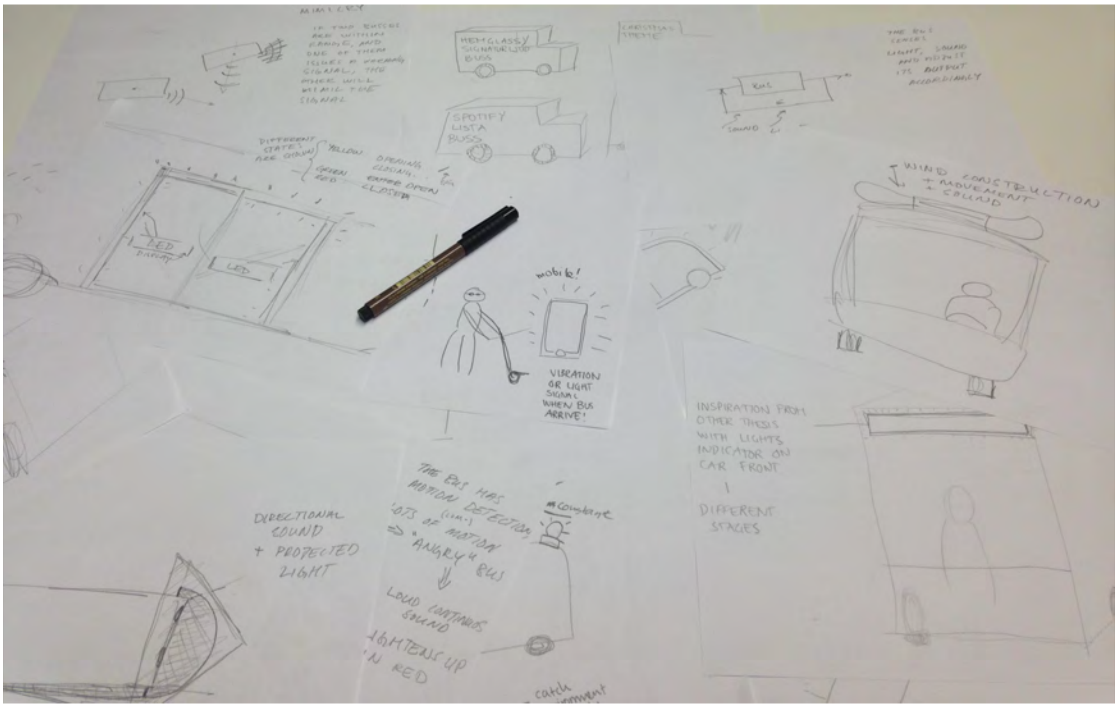


Figure 6.17: A collection of initial sketches during the first iteration in the design phase.

Transformation

In the transformation phase the ambition was to create some audio of our own built upon previous collected audio. We got in contact with Interactive Institute and got to borrow a simple digital instrument kit Little Bits, enabling exploration and creation of audio signals.

Convergence

The user scenarios were tied to locations mentioned in the interviews with the bus drivers. Amongst the many that were mentioned we selected different types, in order to capture as many different scenarios as possible. We merged several personas, since having an auditive deficit persona and an avid headphone user was superfluous.

A presentation where held at Volvo Buses showing our visual sketches and audio prototypes. Received feedback was documented and taken into the next iteration.

6.4.2 Iteration 2

From previous iteration about 15 sounds and 30 sketches where made. For this iteration the focus was to test our sounds and explore new possibilities. A workshop with interaction design students was held which gave us few new ideas, but confirming some previous ideas we had. We also tested the SAM-scale for the first time and learned how to use it and how to not.

Divergence

In order to broaden our own ideas and possibly come up with new, the workshops were held. The workshop consisted of a total of three block where each block consisted of two halves. Part one was about the 6 Thinking Hats while the other part was about evaluating sounds with the SAM-scale. You can read about 6 Thinking Hats in 5.8 and the SAM-scale in 3.3.1.

Figure 6.18: Handmade hats with accompanying role as tools for workshop participants.

By involving 18 interaction design students from our institution, we were able to verify theories that have come up to that point as well as ensure nothing had been overlooked. The interaction designers where all accustomed to being exposed to tests, they where aware of the task and did not seem frightened by the otherwise fairly identified situation. They where also accustomed to use design methods and a majority of the participants had used the method or heard about i before.

Transformation

Holding workshops in combination with our earlier ideas lead to discussions and development of several design concepts. We wanted to make sense of the big amount of sounds we had by categorising them into specific concepts. This was based one opinions brought up during the first half of the workshop.

Convergence

The evaluated sounds from the workshop and the new created sounds were compiled and analysed. We realised some issues with the SAM-scale evaluation using its two main dimensions, valence and arousal. The third dimension dominance was removed as it overlapped the arousal dimension (read more about why this is often done in 3.3.1). We translated the valence scale running from sad to joyful and arousal scale running from calm to active. Both scales used 7 steps each where the middle was counted as neutral. Through the use of a visual measurement method, we were able to avoid unnecessary misunderstandings or misinterpretations that often appears using verbal measurement tools. This also contributed understandable symbols representing faces with different expressions to easier the subjects evaluations of the sound. However we failed with the score sheet not making them simple and clear which in some cases confused testers.
Some conclusions from the workshop could be drawn:

- Scoring sound: A sound will receive higher valence if the previous sound was considered awful.
- Reference sound: The first sound is hard to evaluate and rarely receive the highest or lowest score.
- Order of sound: The testers are concerned of the order and want to adjust their answers relatively.
- Bad score sheet: The SAM-scale should be provided so that the tester points or marks the corresponding mannequin. Denoting answers with numbers where the number translates to a mannequin will not do.
- Naming: The sounds should be given ambiguous names.

We found out that many of the people in our studies, including the workshop participants argued from two polarised viewpoints.

1. It's every VRUs duty as a member of traffic to look out and follow the traffic rule. Hence, it's their own fault if they are careless. Efforts to implement warning signals should be discouraged if they would cause discomfort for others in traffic.

2. The other group argued for the sanctity of every life and that every possible action to prevent it were worth it.

The workshop gave us few new ideas, we mostly rediscovered old ideas we've had. It would've also been better to assign hats to designers that suited that particular role. Having participants trying to be creative when they clearly are better at judging is bad for the whole workshop, even though moderation helps it's hard to change character. After discussion with representatives from Volvo Buses, the lack of reproducibility and manipulation of the prototyped sounds requires another instrument for sound making. Pure Data was recommended and will be considered in next iteration.

6.4.3 Iteration 3

Iteration 3, resulted in the creation of our 3 design concept eco, care and express. These video prototypes for this can be seen in full on our thesis page `http://bergskarlen.nu/thesis_page.html#prototypes`.

Divergence

As a complement some of the audio where created using the visual programming language Pure Data, however this way of creating audio did not leave much room for creation in our point of view, due to focus on programming and strict frames. Instead GarageBand was used and sounds where immediately produced.

Following up on the two polarised standpoints who were observed during the previous workshop we decided to make two different concepts based on these standpoints. The first opinion of every VRUs duty as a member of traffic was translated into a concept named "Eco". It focus more one the electric bus brand and to shape by nature. The bus should stand in the background not interfering with its design, rather opposite.

Transformation

When the concept started to take shape, we began to map our sound to them. We also decided to make some new sounds and swap them out, i.e. many were similar (see Figure 6.19, and we wanted diversity.

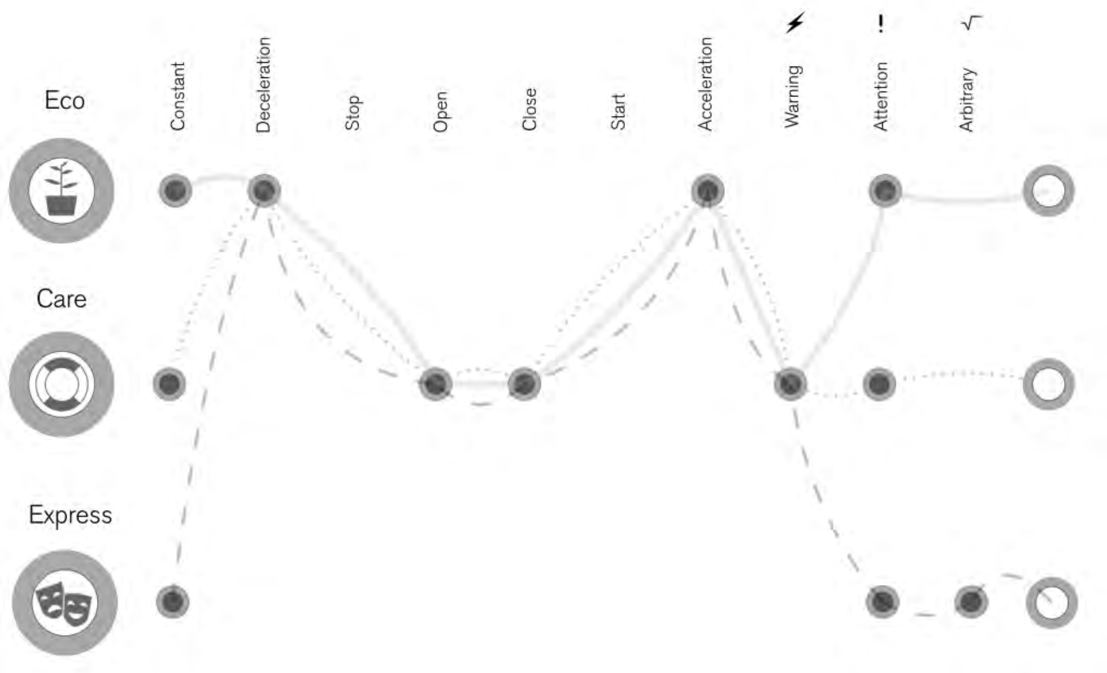


Figure 6.19: Concept - All

Convergence

After the presentation at Volvo Buses we received feedback that our concept was weak. It was not obvious by the concept names what they meant. A a lack of certain audio cues, weakness of concepts and liking of the individual sounds who were received well. Listening to the feedback we simply decided to design the lacking audio cues. Concerning the concepts who was perceived as arbitrary, we concluded that even though the process of creating them were specific and coherent the result was not.

6.4.4 Iteration 4

The feedback from previous iteration changed our point of view and led us away from concepts to focus more on individual sounds and then combine them to a coherent set of sounds. The previous idea was to come up with a concept based on research and make matching sound sets to the concept, which was great for the creative process but not for the result.

Divergence

Sound design of start and stop procedure was carried out. Additional deceleration and acceleration cues was made as well and the original pair was bolstered with increased volume. While the start and stop sound signatures were designed from scratch the acceleration and deceleration pair were designed to fit one of the given constant sounds.

Transformation

The acceleration and deceleration sounds were superposed onto the the constant sound in order to have a smooth transition, as this behaviour signal a increase or decrease of a current property (increase or decrease of speed) rather than a change of state (drive versus stop). To emphasise a change in speed we considered an increased frequency or a temporal change to be effective. When changing states, i.e. stopping or starting we turned into a completely different direction. We believe a state change is signalled best by a sound that's vastly different from the other states. The easiest way to differentiate start and stop sounds from the other sounds were to invert the tempo, making signals with two tones at most. We used sounds similar to notification sounds since it has a well-known social meaning.

Convergence

A audio test was conducted in order to emotionally assess individual audio cues. Again, video prototypes provided the necessary context. The video consisted of seven situations consisting of at least three new sounds each. In total we tested 25 unique sounds. The test was carried out by reading a short introduction about us, what the test was about and what tasks we needed help with. After the tester signed a consent form and answered a few questions about themselves the test was carried out using the SAM-scale. The tester was shown a clip of the bus in a situation, when the clip ended the tester marked down his or her answer by assigning a post-it note to the mannequin 6.20 from the SAM-scale best depicting their feeling. When the testers answer was recorded by the test conductor the next clip was shown and scored until all the clips for that situation were scored. When all the clips depicting a situation were scored the tester was questioned about the meaning of the signal. When the answer was given the procedure was repeated until all clips for the seven situations were scored. The scores that were later elected for the final concept are shown below while results of excluded sounds are found in Appendix A.4. How the selection were made is found next, in the section 7.3.2.

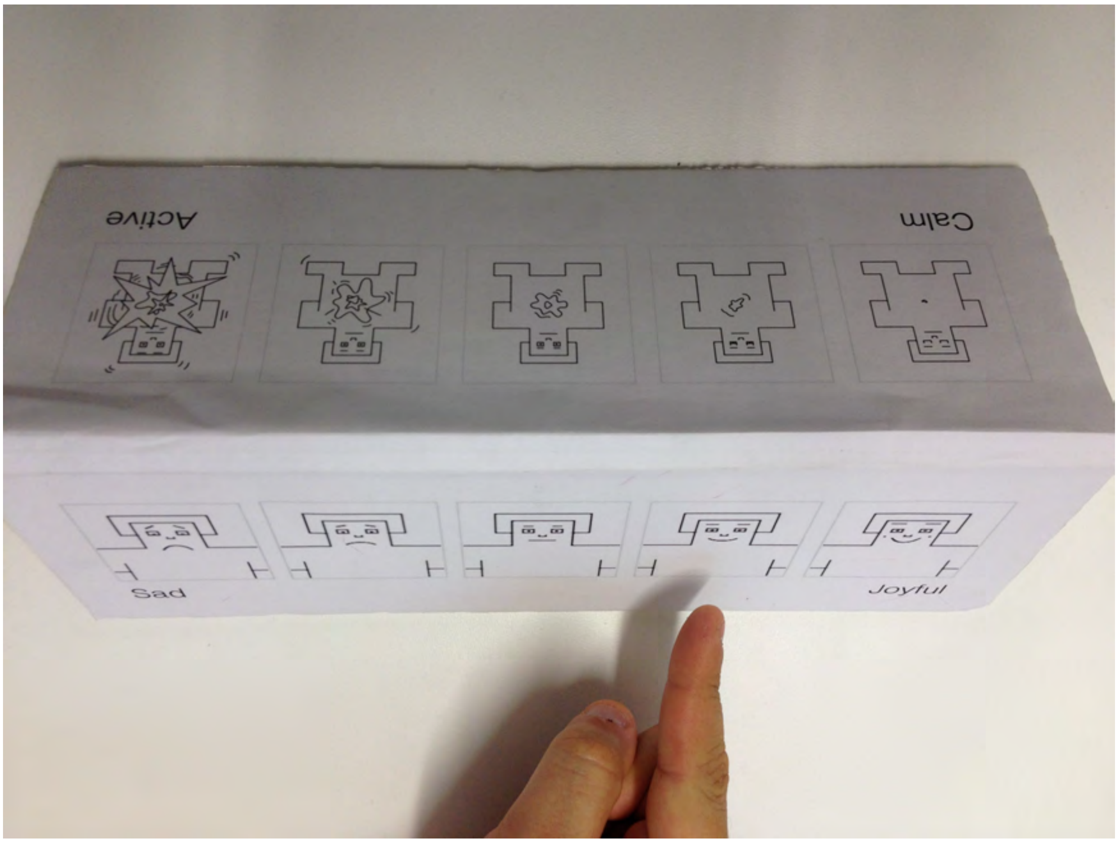


Figure 6.20: A board of the manikin scale was distributed to the testers as a tool for easier judgement.

By performing a test we obtained a score for each sound in terms of two SAM-scale parameters, namely arousal (summarised in A.1) and valence (summarised in table A.2). The guidelines from (Patterson and Authority, 1982) was used to infer results from the test. According to the guidelines, each situation is assigned a level of urgency in a urgency mapping. This level of urgency is associated with a suitable score for the Arousal parameter. Following the line of thinking explained in section 2.1.1 the ranking is given in Table 6.1.

6.5 Phase III - Documentation

The final phase has involved a lot of documentation, which has been necessary in order to condense our design and finding in order for the results to be usable for other researchers of Volvo Buses. A digital reference has created for collection of audio and video prototypes. Interviews and results has been compiled and transcribed for the Appendix.

A final presentation was held at Volvo Buses in August 28 with good results. They

Rank of Urgency	Situation	Desired Arousal
1	I, Warning	5
2	H, Attention	5
3	AB, Deceleration	4
4	F, Start	3
5	AG, Acceleration	3
6	C, Stop	3
7	A, Constant	2
8	DE, Open/close doors	1

Table 6.1: The rank of urgency associated with the situations and the expected degree of arousal related to it.

were satisfied with our work, and plan to take the sounds further for future testing in a safe but more real environment.

7

Results

THE RESULT is a Pattern-Event-Pattern model for warning signal design followed by four concepts that utilised the PEP-model. Within the concept there's four video prototypes depicting when and how audio warning signals are issued. Only three of the concept uses motion tracking in order to showcase how the visual warning signals could appear. All concepts includes visual warning signals, described by sketches.

7.1 Pattern-Event-Pattern model

The PEP-model provided consists of a repeating Pattern or procedure which is interrupted by events but then returns to the Pattern. The purpose of the PEP-model is to emphasis the different design aspects for Pattern or Event. Notably, part of the problem today is the big gap between Pattern and Event as bus drivers refrain from using the warning signal. This gap is due to today's tacit Pattern which makes it discrete in relation to the harsh but necessary horn. The main benefit in our studies is the expansion of Events, allowing the drivers to issue warnings of lower degrees. The benefit is that the discrete scale of danger communicated is finer, while the drawback is that a finer level of danger needs to be communicated.

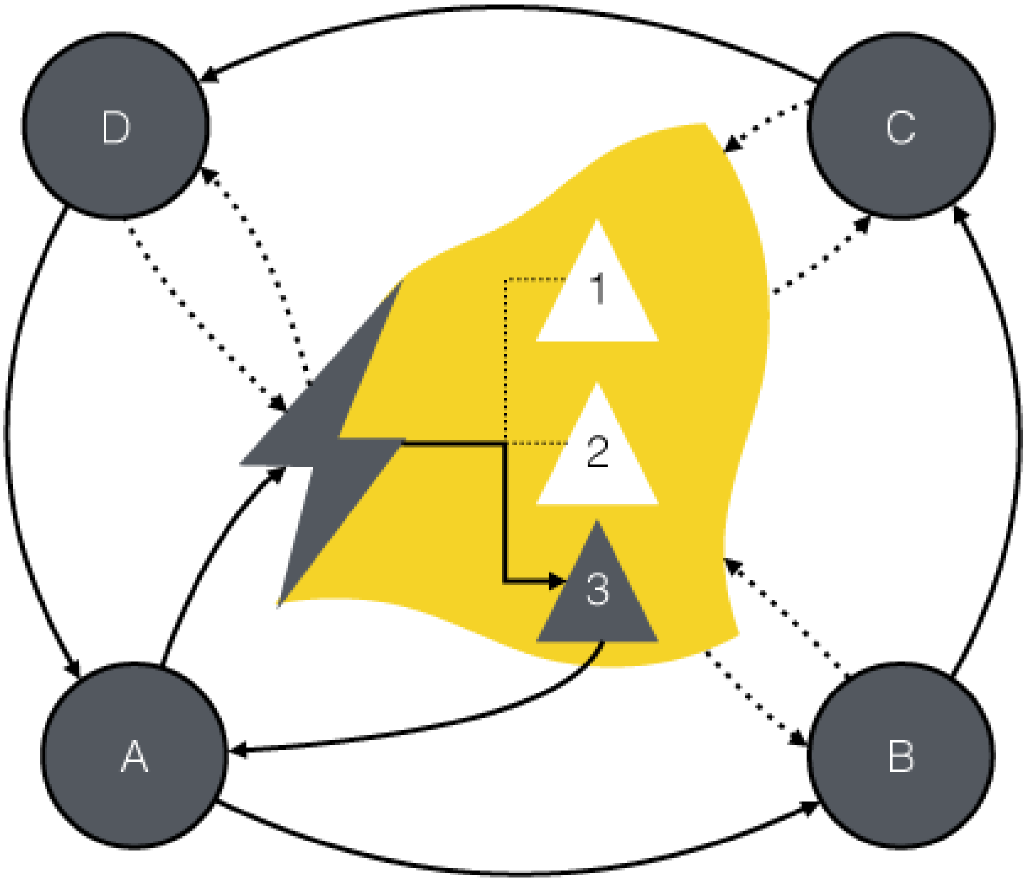


Figure 7.1: The Pattern-Event-Pattern model. The Pattern consists of parts A,B,C and D. The Event consists of three different events, named accordingly. The Pattern part A is interrupted by Event 3, while events at the parts B, C and D weren't triggered

7.1.1 Pattern

The Pattern is a walk through the applications standard behaviour or procedure. Each part of the pattern should be distinguishable from another part. By designing warning signals for every part of the Pattern the application will be cluttered with signals, this is undesirable why comparison, evaluation and elimination is needed. The Pattern constructed in this thesis is based on the platform procedure 6.15. Since the Pattern is repeated frequently it has requirements concerning comfort, valence and health. The warning signals that are associated with the Pattern has the objective to change the long term behaviour of the VRU through interaction between the driver and the VRU.

7.1.2 Events

The Events are occurrences with unpredictable timing, they often breaks the pattern or disrupts the ordinary flow of the application. The Events in this thesis 6.16 comes from disruptions in the traffic situation. A typical event would be a VRU being in front of a moving bus, which demands the issue of an warning signal. This warning signal should be different to the Pattern signals, why it's allowed to break coherency, aiming for maximum attention. It's the events objective to announce an impending accident so that the VRU has the chance to evade it.

7.1.3 Separation between Pattern and Event

Some events could be described as part of the Pattern and some parts of the Pattern could be described as events. This is exemplified by the open and close doors which could be regarded as an event rather than a part of the Pattern. Since the vast majority of all platform procedures includes door openings we consider it to be a part of the Pattern. After all, it's the purpose of the bus to transport people.

7.2 Three concepts

Three concepts where elaborated from the basis of our main stakeholders and the . The first is based on the viewpoint that silent buses aren't dangerous, why the warning signals should be focused on branding and creating a coherent experience. The second is based on the belief that every life is sacred and taking every measure to save it is worth it, probably on the expense of sensory load. The third is all about the interaction between the VRU and the bus driver, mainly by giving the driver more ways of expressing her- or himself.

7.2.1 Eco

With the Eco concept follow some finalized sketches. Picture 7.2 shows how the warning lights around the door could behave from an eco perspective. By placing a light list inside the door, this could be used as a progress bar of how much the door is open or closed. Our interviews with visually impaired people revealed that large portions of light at eye level makes the visibility significantly better and the opportunity for everyone to see information increases. More sketches of the Eco concept can be found in Appendix E.1.

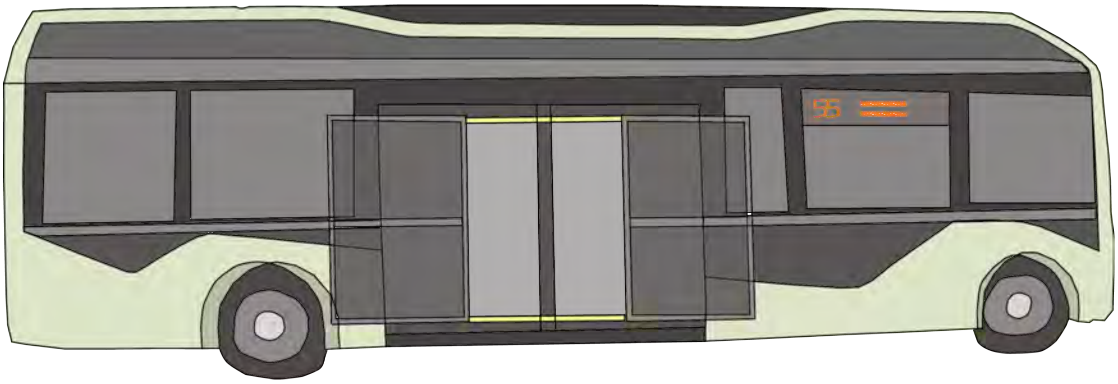


Figure 7.2: Sketches of the concept Eco

7.2.2 Care

The other opinion argued for the sanctity of every life. The concept based on this opinion is ”Care”. The bus in this concept aim at babysitting the road user and prevent every possible accident or danger. As with sketches of the Eco concept long trail of light is used. Two vertical light bars indicates how much the door is open and will prevent people getting squeezed in the door. This is presented in Figure 7.3. Another light concept concerned the side mirrors, highlighting it with bright colour and sound to get attention when needed. Also an idea was to highlight parts of or the whole front to enlighten and inform the road users. These sketches can be found in Appendix E.2.

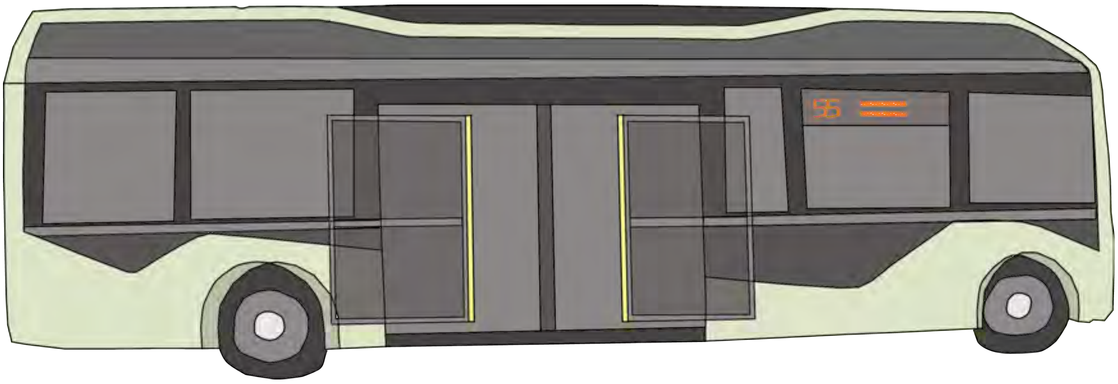


Figure 7.3: Sketches of the concept Care

7.2.3 Express

A third concept was created with the arbitrary event in mind, named ”Express” By enabling information onto the bus we wanted to make it possible for the bus to express its actions like feelings. The road user can learn the behaviour of the bus after being located in the city traffic environment. Sketches 7.4 and 7.5 illustrate the count down of the warning signal for the doors on the electrical bus concerning the express concept.

Another idea was to use the arbitrary traffic light for crossing the road. By putting the green and red man on the side mirrors, the driver could express his intentions and the road user get an indication of the situation. These sketches can be found in Appendix E.3. We also had a wilder idea in mind, which is based on an artefact designed for the bus driver. When the bus driver squeezed the artefact she or he issued a warning sign but depending on how pressure was applied, the sound would be different. By manipulating the sound themselves they could create an arbitrary language to be interpreted by VRU, passengers and even other bus drivers. Having a squeezable artefact serves two purposes, the first is that it could utilise muscle memory which is important since it adds less to the drivers cognitive load. The second purpose is the similarity or association to stress relief. By connecting a stress relieving hand motion to a calming sound the VRU could notice the bus drivers emotional state. This idea is well beyond the scope of this thesis as it requires a thorough investigation of the feasibility of using such an artefact. Arbitrary signals are probably legally constrained and the cognitive load would be increased. Complex social dynamics would also be a probable result of such an artefact.

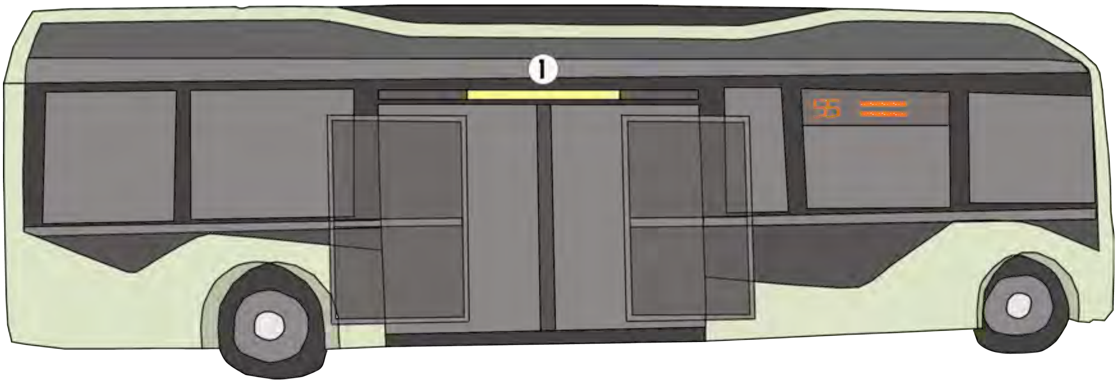


Figure 7.4: Sketches of the concept Express, state 1

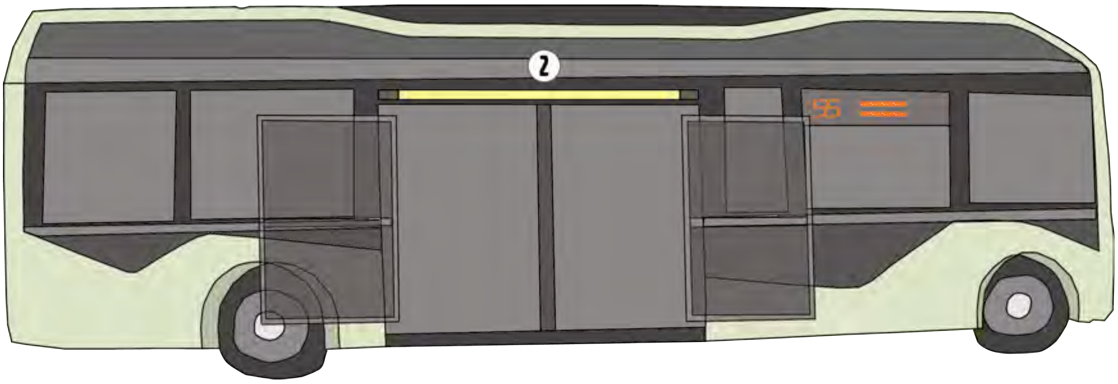


Figure 7.5: Sketches of the concept Express, state 2

7.3 Exterior Warning and Attention Signal

Exterior Warning and Attention Signal or EWAS, is the concept from the final iteration. It's presented through a video prototype which is found under heading "Final Concepts" `http://bergskarlen.nu/thesis_page.html#prototypes`.

7.3.1 Visual warning signal

The temporal property of the visual warning was investigated. A anthropomorphic behaviour was given by pulsating lights, simulating heartbeats. The signal is contained to the platform, as legal issues arises with pulsating lights outside the platform environment. A demonstration of the temporal properties is given here: `http://bergskarlen.nu/thesis_page.html#sketches`. The platform state is described by 7.6 and 7.7, while the door state is shown in 7.8. The colour change indicates a change in state, as the bus is safe to embark when yellow.

Figure 7.6: Sketches of the concept EWAS, platform state

Figure 7.7: Sketches of the concept EWAS, platform state

Figure 7.8: Sketches of the concept EWAS, door state

7.3.2 Selection of sounds

By reviewing the results from the audio test 6.4.4 a selection of sounds was made to fit each situations urgency rank. A preference was made towards sounds with higher valence in order to create a positive response, which is good for marketing but arguably not as good interaction design, as user experience might be enriched by using negative emotions (Fokkinga and Desmet, 2013). This topic is expanded in 8. The selection is founded in the data results of the audio test. The data is given as a table of the current test case accompanied by a scatter plot of the selected sound with two sub plots that summarizes all other sounds. A guide how to read box plots is given here: `https://plot.ly/box-plot/`, please note that uniform data will be presented as a line as quartiles coincides with the median. All the scatter plots are found on the homepage.

Situation	Chosen Sound	Urgency Rank	Desired Arousal	Meas. avg. Arousal	Meas. avg. Valence
Platform procedures					
A, Constant	Sound 3	7	2	2.33	3.28
AB, Deceleration	Sound 1	3	4	3.39	3.06
C, Stop	Sound 4	6	3	2.94	3.39
DE, Open/close doors	Sound 4	8	1	2.44	2.56
F, Start	Sound 3	4	3	3.00	3.50
AG, Acceleration	Sound 2	5	3	4.00	2.11
Events					
H, Attention	Sound 3	2	5	2.33	3.00
I, Warning	–	1	5	–	–

Table 7.1: The rank of urgency associated with the situations and the expected degree of arousal related to it. Note that Event I, Warning isn't evaluated due to being the horn currently used in traffic.

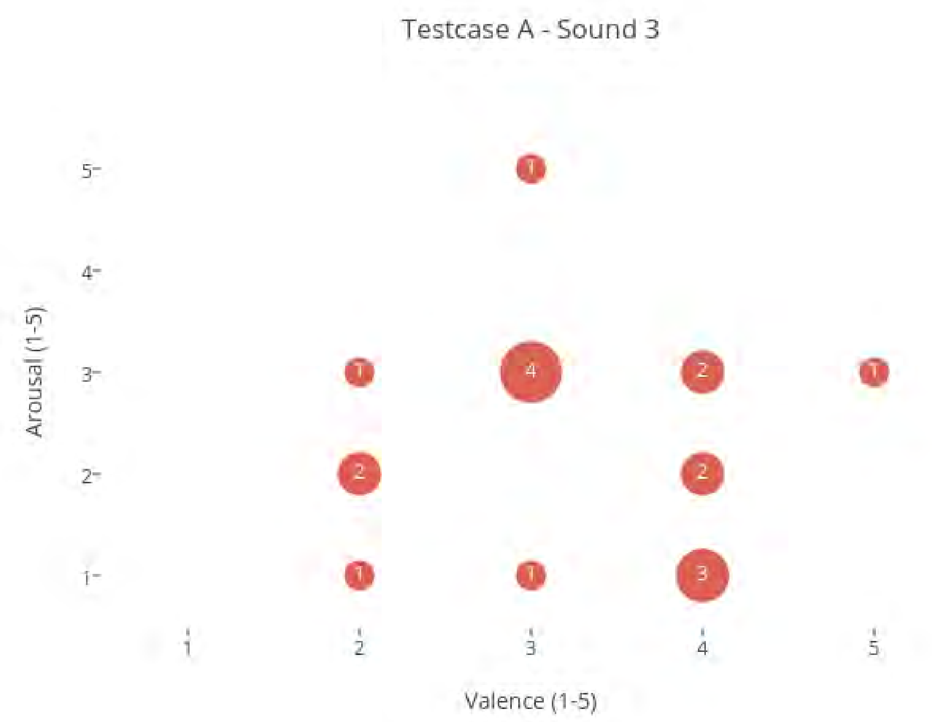
Result of test case A - Constant

Sound 1 and sound 3 received similar score while sound 2 scored low in valence and high in arousal. As the urgency mapping associated with this sound is low, a high score in arousal eliminates the sound. Notably Sound 2 was preferred by Volvo Buses sound expert Pontus Larsson who points out that its high frequency enables an easier technical implementation. This fits with our findings, high frequency sounds tends to be annoying but usually cuts through background noise better than low frequency sounds. As sound 3 has a more continuous character compared to Sound 1, it makes a more coherent choice for a sound describing continuous motion. We think that sound 3 is better, even though the arousal of sound 1 is closer to the desired arousal 2. We believe the slight difference, only 0.28 for sound 1 and 0.33 for sound 3, is less important compared to the coherence that sound 3 provides. More serious is the significant spread in arousal shown in Figure 7.9b. We still believe that Sound 3 is better due to coherency though.

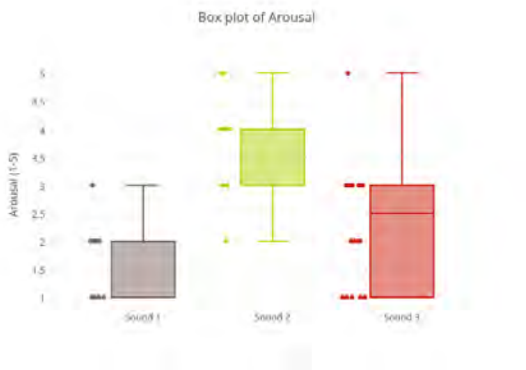
Test Case A - constant sound

Observations $n = 18$	Min/max		Mean		Variance	
	Valence	Arousal	Valence	Arousal	Valence	Arousal
Sound 1	(2, 5)	(1, 3)	3.11	1.72	0.93	0.33
Sound 2	(1, 3)	(2, 5)	1.78	3.78	0.65	0.54
Sound 3	(2, 5)	(1, 5)	3.28	2.33	0.80	1.18

Table 7.2: The valence and arousal score for the constant sounds in terms of extremes, mean and variance.



(a) Shows a scatter plot of Sound 3 for test case A. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



(b) The arousal parameter summarized by box plots for each sound in the test case.

(c) The valence parameter summarized by box plots for each sound in the test case.

Figure 7.9: The test answers for case A. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.

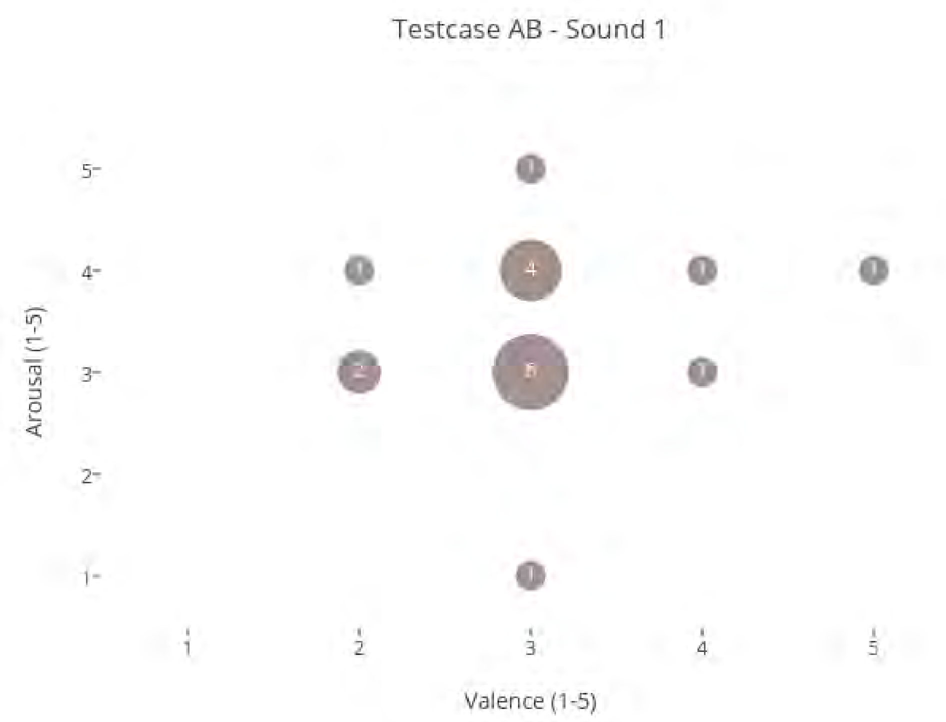
Result of Test Case AB - Deceleration

Sound 1 and sound 3 scores within range of the desired arousal, while sound 2 is discarded despite being having the best valence score. More important than the average score in arousal is the spread, why we select sound 1. The spread of sound 3 is shown in Figure 7.10b and has a huge diversity comparing to sound 1. Note that the valence score for Sound 2 and Sound 1 were so uniformly distributed that the box plot was reduced to a dash. When selecting this sound we pay attention to which sound was selected in the previous test case. It's important that signals with different meaning are significantly different from each other. Hence the pair of sound 3 from Test Case AB and sound 1 from Test Case A would match, since they are continuous and rhythmic. The pair of sound 1 from Test Case AB and sound 3 from Test Case A would also match well, since they are rhythmic and continuous.

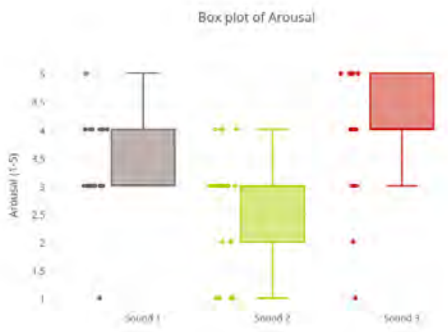
Test Case AB - deceleration

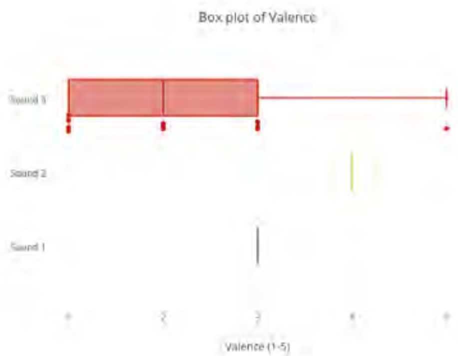
Observations	Min/max		Mean		Variance	
$n = 18$	Valence	Arousal	Valence	Arousal	Valence	Arousal
Sound 1	(2, 5)	(1, 5)	3.06	3.39	0.53	0.72
Sound 2	(2, 5)	(1, 4)	3.83	2.61	0.38	1.08
Sound 3	(1, 5)	(1, 5)	2.11	4.00	1.16	1.29

Table 7.3: The valence and arousal score for the deceleration sounds in terms of extremes, mean and variance.



(a) Shows a scatter plot of Sound 1 for test case AB. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful





(b) The arousal parameter summarized by box plots for each sound in the test case.

(c) The valence parameter summarized by box plots for each sound in the test case.

Figure 7.10: The test answers for case AB. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.

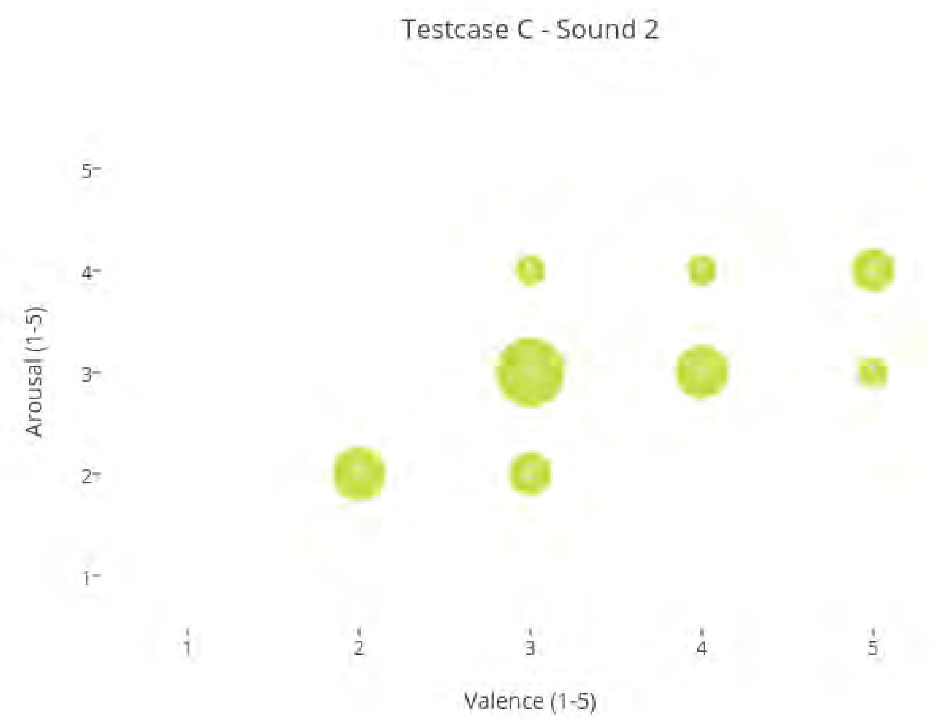
Result of Test Case C - Stop

All sounds where close to the desired arousal of 3. Sound 3 has rather low valence compared to sound 1 and sound 2, why it is cut out. We agree with the sound not fitting the situation. Sound 1 had the highest valence of 4.17 along with the highest arousal 3.50. However sound 1 exceeds the arousal in the selected sound from Test Case AB, which result in unwanted urgency mapping order. We as designers believe 1 might have gotten a to high arousal score, maybe caused by the context it appeared in. However since sound 1 and sound 2 both are good choices we decided to select sound 2 for winning sound, Test Case C. Sound 2 has an arousal of 2.94 which makes a match for desired arousal along with a high valence of 3.39. Also looking closer at the plot of arousal for sound 2, the span of responses is narrow (2-4) which points at an almost unambiguous result, meaning most testers thought that sound 2 was a good choice.

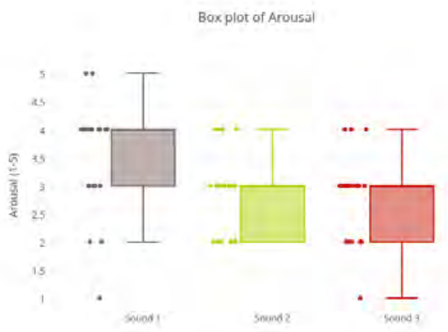
Test Case C - stop

Observations	Min/max		Mean		Variance	
$n = 18$	Valence	Arousal	Valence	Arousal	Valence	Arousal
Sound 1	(2, 5)	(1, 5)	4.17	3.50	0.85	0.16
Sound 2	(2, 5)	(2, 4)	3.39	2.94	0.96	-0.99
Sound 3	(1, 4)	(1, 4)	2.33	2.78	0.59	-0.30

Table 7.4: The valence and arousal score for the stop sounds in terms of extremes, mean and variance.



(a) Shows a scatter plot of Sound 2 for test case C. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



(b) The arousal parameter summarized by box plots for each sound in the test case.

(c) The valence parameter summarized by box plots for each sound in the test case.

Figure 7.11: The test answers for case C. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.

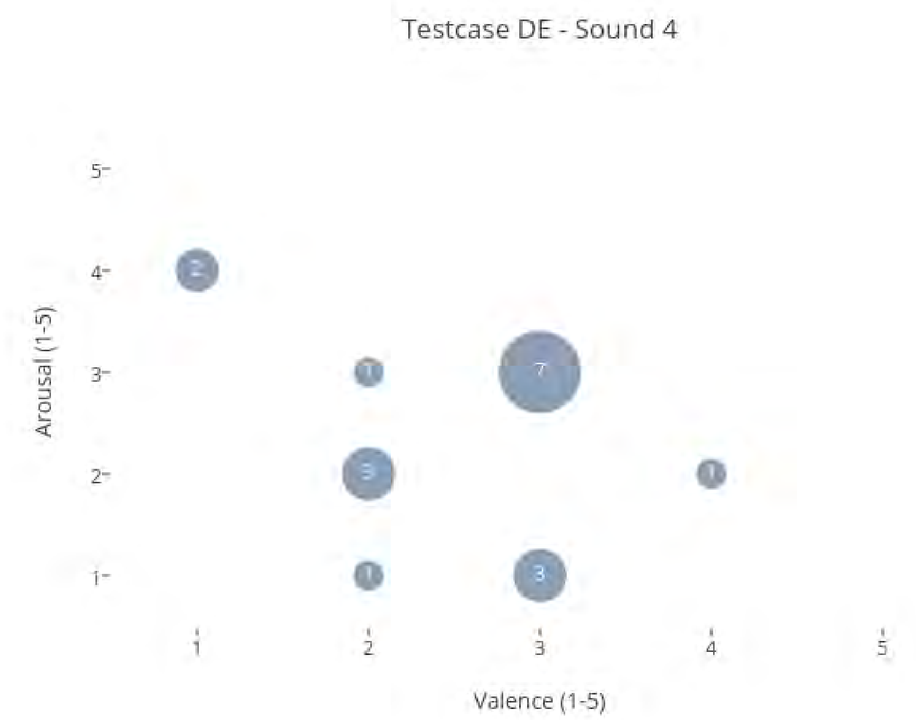
Result of Test Case DE - Open/close

Desired arousal was set to 1. Neither of the tested sound fulfil this but notably was sound 4 which received the lowest arousal. This is notably since we designed that sound especially to mimic the mechanical sounds issued by existing bus doors. The reason being that the existing mechanical door sounds does a great job at explaining the door state, e.g. the unlocking sounds actually relates to the hatches which unlocks the door. The problem with mechanical sounds is that they are naturally reactive which is discussed in 8.4.8.

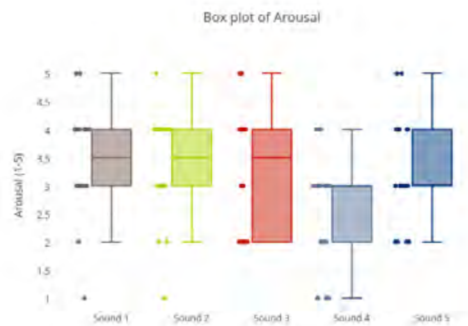
Test Case DE - open/close

Observations	Min/max		Mean		Variance	
$n = 18$	Valence	Arousal	Valence	Arousal	Valence	Arousal
Sound 1	(3, 5)	(1, 5)	3.89	3.44	0.58	0.97
Sound 2	(3, 5)	(1, 5)	3.83	3.33	0.62	0.94
Sound 3	(1, 5)	(2, 5)	2.28	3.28	0.80	1.15
Sound 4	(1, 4)	(1, 4)	2.56	2.44	0.61	0.97
Sound 5	(2, 5)	(2, 5)	3.83	3.22	0.62	0.89

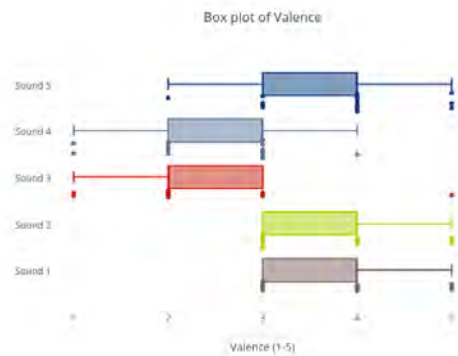
Table 7.5: The valence and arousal score for the open/close sounds in terms of extremes, mean and variance.



(a) Shows a scatter plot of Sound 4 for test case DE. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



(b) The arousal parameter summarized by box plots for each sound in the test case.



(c) The valence parameter summarized by box plots for each sound in the test case.

Figure 7.12: The test answers for case DE. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.

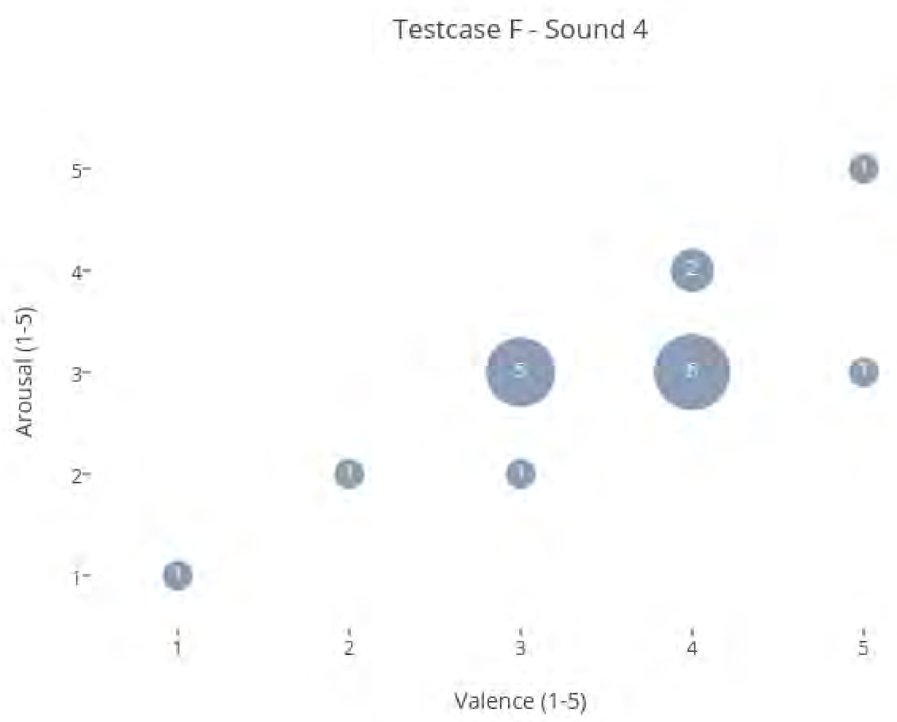
Result of Test Case F - Start

Sound 2, sound 3 and sound 4 was eligible due to the desire arousal. Sound 1 was discarded due to an immense spread and general low arousal. A closer look at the plot 7.13b reveals majority of the tester selected desired arousal 3 for sound 4, this shows as a simple line, meaning none or low spread. Even though sound 2 and sound 3 have higher valence score than sound 4, we believe sound 4 to concise of a more narrow span which is more desirable.

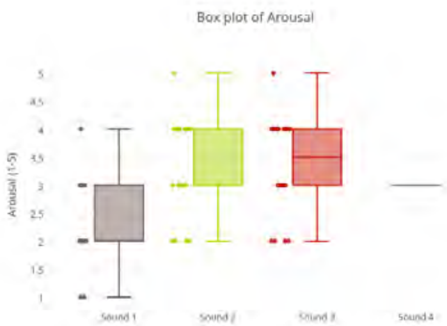
Test Case F - start

Observations	Min/max		Mean		Variance	
$n = 18$	Valence	Arousal	Valence	Arousal	Valence	Arousal
Sound 1	(1, 5)	(1, 4)	3.22	2.22	1.12	0.54
Sound 2	(2, 5)	(2, 5)	3.72	3.28	0.68	0.80
Sound 3	(1, 5)	(2, 5)	2.94	3.33	1.58	0.82
Sound 4	(1, 5)	(1, 5)	3.50	3.00	0.97	0.71

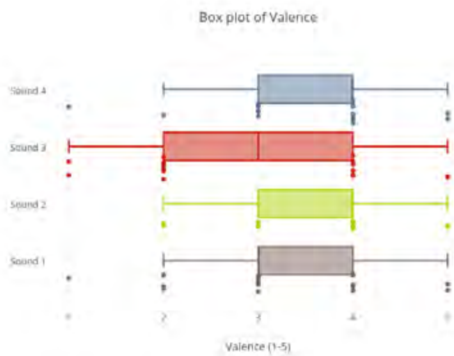
Table 7.6: The valence and arousal score for the start sounds in terms of extremes, mean and variance.



(a) Shows a scatter plot of Sound 4 for test case F. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



(b) The arousal parameter summarized by box plots for each sound in the test case.



(c) The valence parameter summarized by box plots for each sound in the test case.

Figure 7.13: The test answers for case F. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.

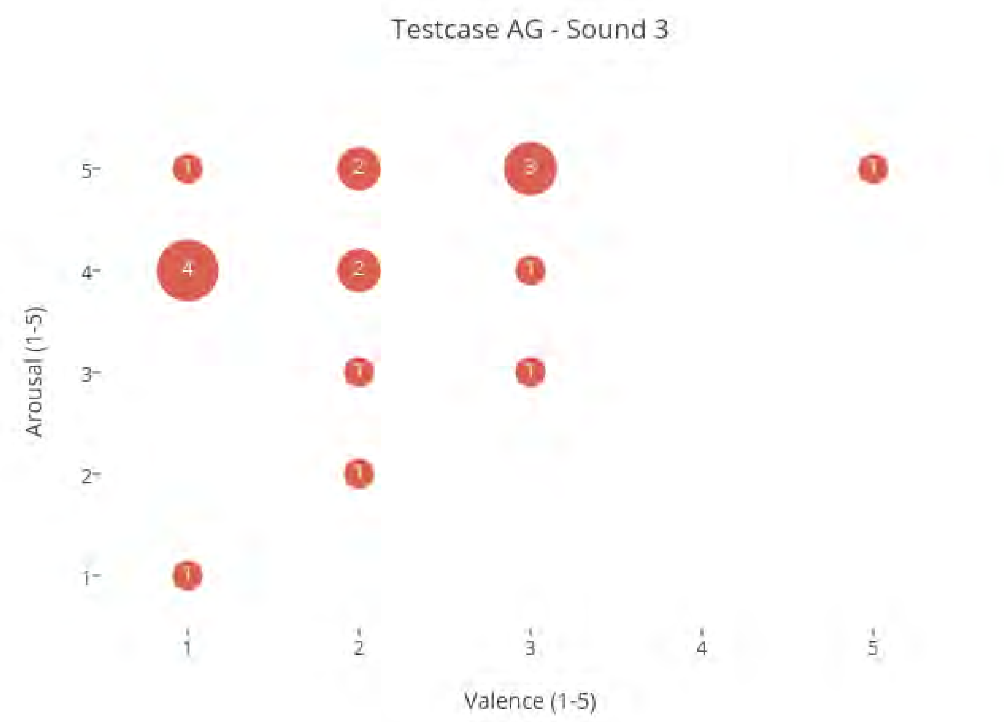
Result of Test Case AG - Acceleration

Both sound 1 and sound 3 scored to high arousal. Desired arousal was set to 3 and as argued earlier selected sound for Test Case AB scored 3.39 of an desired arousal of 4. We aim to not change the urgency ranking and therefore select sound 2 with a more suiting arousal level even though it falls below desired arousal.

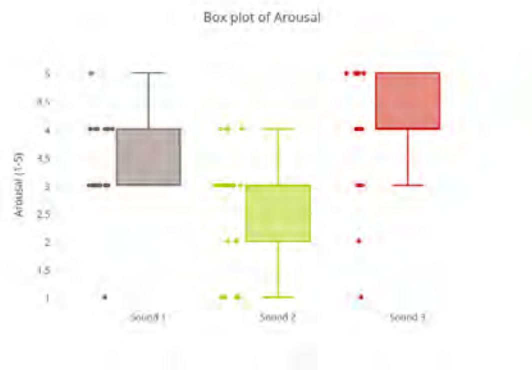
Test Case AG - acceleration

Observations	Min/max		Mean		Variance	
$n = 18$	Valence	Arousal	Valence	Arousal	Valence	Arousal
Sound 1	(2, 5)	(1, 5)	3.06	3.39	0.53	0.72
Sound 2	(2, 5)	(1, 4)	3.83	2.61	0.38	1.08
Sound 3	(1, 5)	(1, 5)	2.11	4.00	1.16	1.29

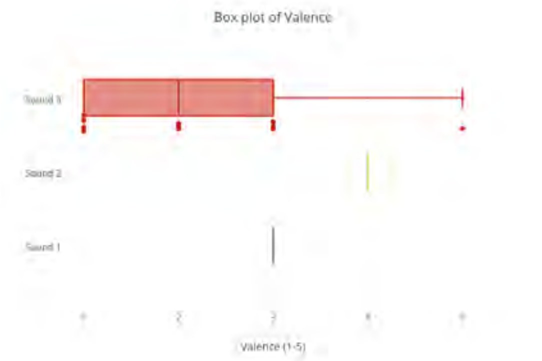
Table 7.7: The valence and arousal score for the acceleration sounds in terms of extremes, mean and variance.



(a) Shows a scatter plot of Sound 3 for test case AG. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



(b) The arousal parameter summarized by box plots for each sound in the test case.



(c) The valence parameter summarized by box plots for each sound in the test case.

Figure 7.14: The test answers for case AG. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.

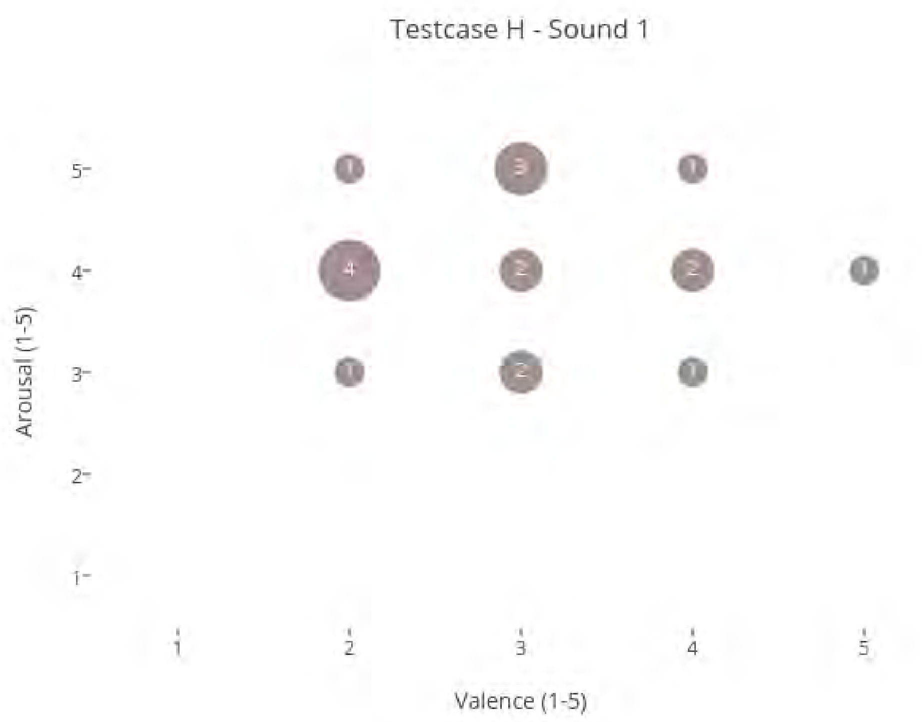
Result of Test Case H - Attention

All sounds scored relatively low in arousal. However sound 1 differed some in all categories and was received very well at our presentation at Volvo Buses.

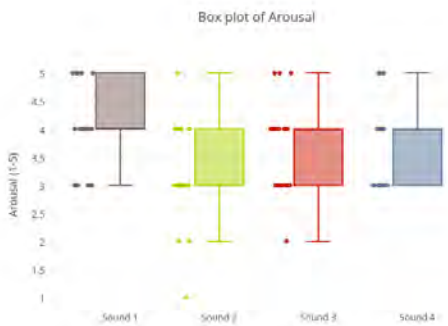
Test Case H - attention

Observations	Min/max		Mean		Variance	
$n = 18$	Valence	Arousal	Valence	Arousal	Valence	Arousal
Sound 1	(2, 5)	(3, 5)	3.00	4.06	0.82	0.53
Sound 2	(1, 5)	(1, 5)	2.44	3.11	1.56	0.81
Sound 3	(2, 5)	(2, 5)	3.44	3.67	0.61	0.71
Sound 4	(1, 5)	(3, 5)	3.44	3.78	1.56	0.54

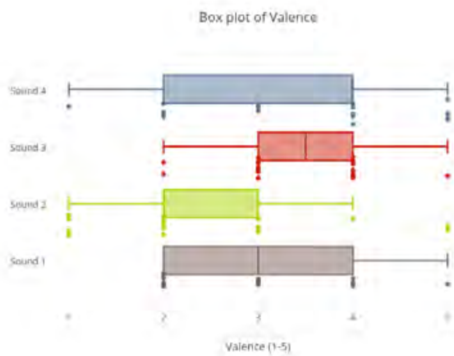
Table 7.8: The valence and arousal score for the attention sounds in terms of extremes, mean and variance.



(a) Shows a scatter plot of Sound 1 for test case H. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



(b) The arousal parameter summarized by box plots for each sound in the test case.



(c) The valence parameter summarized by box plots for each sound in the test case.

Figure 7.15: The test answers for case H. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.

8

Discussion

THIS CHAPTER will review our main research question along with its two sub questions stated in the beginning of this master thesis. The statements are grounded in the research and design work, complemented by the results from previous chapter. Further we evaluate some design insights and look in to further work that could follow up this project.

8.1 Introduction

Many alternatives come to mind designing warning signals. During this project several suggestions have been made involving using loud speakers using voice messages or different kinds of signals that adjust volume to suit a situation of how to bring attention to the road users. We initially adopted many of these suggestions to try them out. As described in the design process 6.4.1 we borrowed a directional loudspeaker, however when testing we realised that this was not in line with the message that the drivers wanted to share. Unwanted attention is brought onto the VRU from the driver. Voice message could have been a good solution thinking about visual and hearing impaired people, since it brings a higher attention to a situation and brings information of what is going on. However as the project continued and along with visual and auditory theory about warning signals we believe that less is sometimes more. By simplicity we can put attention on what is really necessary, also using voice brings up a discussion about language barriers. Further we aimed at creating smart sounds and lights that could measure volume and light in the city surrounding and adjust warning signals accordingly. However we did not apply this technical feature in our thesis due to limitations such as technical expertise and human centred design focus instead, but we highly believe that it should be implemented that way. To motivate further we as interaction designers came into the project to leave the technical aspects for the audio design team within Volvo Buses and put our human focus in centre.

8.2 The main research question

How can exterior warning signals for silent buses be designed, in order for them to be effective yet comfortable?

Designing a warning signal include many factors often overlooked. We highlight two main factors to keep in mind while designing exterior warning signals for silent buses to be both effective and comfortable. The first factor indicates the importance of having a situation in mind when designing. In our master thesis, we developed user scenarios to map the interaction between the bus and the VRU. Important requirements were identified and the design process was shaped by them. Furthermore, use cases were developed to create a clearer exterior interaction from the bus. It consisted of two parts, the platform procedure and the events. Shortly the platform procedure identified and described the behaviour of the bus at a platform and how warnings could play a role in that situation. Events touched upon what type of warning suited in different situations.

The second factor is about testing the warning signals with a context, preferably in reality. Understanding the importance of iterations, to improve and innovate the product as new tests yields new results. The results further show the importance of testing the warning signals in a situation that allows context, due to the background noise of city traffic that either suffocate or emphasize a sound or a warning in an irregular way that is difficult to reproduce in a lab environment. While it's preferred to test in the real world it's important to not expose people to danger in the process. By creating rapid prototypes and quickly get out into a safe and natural environment, progress can be made and the short quick iterations can produce good results.

8.2.1 PEP-model

The PEP-model described in 7.1 doesn't investigate events occurring in between parts in the Pattern. It's hard to define the transitions between some parts, e.g. deceleration and stop in the platform procedure. This difficulty indicates that a individual warning signal for the two parts of the pattern might be unnecessary, which was the case for deceleration and stop as the warning signal for stop was discarded. Another transition that was tricky to differentiate were constant and deceleration, but here we kept the two warning signals, part due to legislation forcing us to keep the constant sound.

8.2.2 Designed prototypes

From the final convergence phase 6.4.4 in the design process we obtained a final concept presented in the result chapter7. This concept is shown through a video prototype and accompanied with functional sketches. The final video prototype can be found at `https://vimeo.com/137401990` however a password is required [1]

[1] Email idajaehie@gmail.com for access to the videos.

By reviewing the concept we decided to cut some sounds. Firstly the door sound should be replaced by a mechanical sound, the sound we designed (we designed such a sound as reference) is usable but the real sound is probably enough and provides the benefit of being related to its own movement. Having paired sounds like acceleration and deceleration or stop and start is superfluous. Often users confuses the two sounds as they're similar. They're designed to be each others opposites but to no avail. If the user thinks it's the same then it is sane to remove it (Maeda, 2006). To not confuse the user we allow one type of sound correspond to one action. We decided to eliminate the stop sound since it occurs after the deceleration sound and in the same manner we decided to eliminate the acceleration sound as it occurs after the start sound. We also experimented by removing additional sound. The final concept video prototype can be found at `https://vimeo.com/137402217` and every video prototype is available at `http://bergskarlen.nu/thesis_page.html#results`.

8.3 Research questions

Recalling the first research question from section 1.1:

Are multi-modal warning signal beneficial in order to increase the level of comfort, effectiveness or both? Which mode is suitable?

The suitable modes are visual and auditory, tactile being possible but not suitable[2] as the purpose of a warning signal is to avoid tactile interaction between bus and vulnerable VRUs.

Audio signals are dominant and reaches the users who is in dire need of the warning. The audio warning signals should be mapped to the highest urgency which corresponds to a higher sensory load. High frequency sounds are generally, but not always, less comfortable and more effective while the low frequency is more comfortable but less effective. Propulsion with a combustion engine typically produces low frequency noise.

The proposed sounds are evaluated and reviewed by experts at Volvo, though extensive testing remains to show if they're good enough for commercial use. The sounds will also require tuning in order to fit them to speakers and an acceptable volume.

Visual warning systems mainly provide information. Since the information can be utilised to prevent irrational behaviour the vulnerable VRU might benefit in the long term rather than immediate. The lack of immediacy makes the visual signal less of a warning signal why it's given a very low urgency mapping. By replacing audio warnings of lower urgency with visual warnings the sensory load might be lowered but it remains to be properly tested.

To summarize, audio warning signals are effective but not comfortable. By combining an audio warning signal with lower urgency with a visual warning signal of higher urgency will probably not achieve a higher urgency than the audio warning signal. The reason being that visual signals lack the dominance that's associated with sound. This

[2]Other modes, such as olfactory (smell), gustatory (taste), kinaesthetic (physical learning) seems far fetched and wouldn't be commercially or socially accepted as solutions.

statement remains to be properly tested.

Recalling the second research question from section 1.1:

To which extent does our warning signals fulfil the current legal requirements, the pending legislation and recommended guidelines?

As the pending legislation consists of AVAS which only concern constant sound, only those three sounds are shown in table 8.1. AVAS and other legal documents are available online[3]. The AVAS-requirements listed in 1.1.1 are repeated:

Requirements

(i) sirens, horns, chimes, bells

(ii) emergency vehicle sounds

(iii) alarm sounds, fire, theft and smoke alarms

(iv) intermittent sounds

Recommendations

(v) melodious sounds

(vi) insect or animal sounds

(vii) any sound that confuses the identification of the vehicle and/or its operation.

	Legislation criterion						
	Requirements				Recommended		
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
Sound 1	Pass	Pass	Pass	Fail	Fail	Pass	Possibly
Sound 2	Fail	Pass	Pass	Pass	Pass	Pass	Possibly
Sound 3	Pass	Pass	Pass	Pass	Possibly	Pass	Possibly

Table 8.1: The constant audio warning signal compared to AVAS requirement. Pass means the current requirement is passed, Fail means failure of the requirement and Possibly means that there's room for interpretation. Note that the column Vehicle confusion only contains Possibly as no sound are similar to a usual bus sound.

[3] `http://bergskarlen.nu/thesis/documents/legislation_docs.zip`

Note that all the constant sounds are possibly confusing (vehicle confusion), as they no longer sound like a bus. This will change as a greater proportion of the bus fleet consists of electrical buses. The criterion are open for interpretation, e.g. no definition of what constitutes a melody is given in AVAS.

Looking separately at every sound, the Sound 3 possibly pass the AVAS requirement. Where Sound 1 and 2 failed.

The AVAS document consists of two parts where the first describe sounds restricted from use under AVAS and the other part sounds recommended to just avoid. If not following the recommendations, Sound 3 pass the AVAS requirements.

8.4 Design insights

Methods used in the design process are constantly changing for interaction designers, to allow adaptation for what one does, and / or discover along the way. So it has been concerning this master work as well, which makes it appropriate to share our design insights that came up during our work.

8.4.1 Inclusive design perspective

The inclusive design perspective was key to enter the field, but it's hard to see how the final concept is about inclusive design. The main reason probably being the lack of testing with users with limited visual or audio capability. The inclusive design perspective was stronger in the research stage, where we gained lots of insight. A good reason for using it was also to discover an already implemented solution, designed for audio. A lot of this insight echoed throughout the design phase but the convergence phases primarily consisted of evaluation through expert statements and user testing, which lacked the inclusive design perspective.

8.4.2 Interview subjects

An interesting thing to bring up is that the very nice bus drivers that we had the opportunity to accompany a full day of observation and interviews. They were selected to drive the new electric buses in Gothenburg and therefore probably was both positive towards the electric bus and its place in the city. To only interview very friendly and acquiescent drivers could possibly effect material extracted, however we followed them a whole day, saw them get quite upset several times due to road users not paying attention in traffic causing the bus drivers to either hit the breaks, signal the horn or just getting irritated due to irresponsible behaviour. But in some sense the results from talking and observing these bus drivers might be biased since the driver were nice. It could also be translated into culture to avoid being rude or get too much attention by making a scene through honking.

8.4.3 Personas

Personas weren't as helpful as they would require a much more thorough research in order to be fruitful. This probably relates to the lack of ethnographic studies. We were simply unable to identify a specific user group that could be described with a persona, in order to design with that specific persona in mind. We discussed them which gave us a lot in the beginning but gradually they faded as the project progressed.

We didn't really use personas as a communication tool either since it did not fit and the communication was already good and clear. Instead the user scenarios contributed with great usability as including a larger user group.

8.4.4 Evaluation method

We relied very heavily on one evaluation method in our user tests. This meant that we gained deeper knowledge of the SAM-scale as we used it twice and used the knowledge from our first session. The problem with reusing the same evaluation method is the lost opportunity to triangulate. As only one evaluation method was used, we couldn't see the flaws of using the SAM-scale, verify findings or reflect upon conflicts between two evaluation methods. As the second usage of the SAM-scale was immensely better we still think it was the right choice - otherwise we might have ended up with two methods and two vague evaluations. More concrete we learned from the fist session that using pen and paper for scoring on the SAM scale the result where not as intuitive as pointing directly at a result like we did the second time around. The authors of the SAM scale emphasize this part and prays it for its usability of intuitive easy of use.

8.4.5 Chosen design medium

All designs that were sketched were typically visual. In the same way almost all designs from discussion were based on audio. It's clear that the medium in which the design is created dictates the medium of the output. Another example of this were the rapid prototyping conducted with Little Bits which were extremely faster than Pure Data. This was surprising to us as every component of Little Bits is available in Pure Data but with more detail, besides simplicity we believe that the creative process involving programming is more time consuming than tangible manipulation. Not surprisingly, GarageBand led to more use of synthesisers in comparison to Pure Data. Additionally doing all the audio ourself definitely limited us in the process compare to having a sound designer doing it for us. It would have been easier to get some sounds or specification from the beginning but what Volvo Buses wanted was a par of new eyes with an open mind. They wanted us to go a little bit crazy and not to be limited. Also we believe that a lot of things is happening in communication with the medium which makes it important to design things yourself as designers.

8.4.6 Use of design concepts

While the concepts were perceived as vague and arbitrary they were very useful for us in the design process. Focusing on a specific concept sparked our creativity and gave us momentum towards new directions. During this process we came up with an artefact for sound manipulation which the bus driver could utilize to communicate. By having this form of expression the drivers could create their own language to be understood by the VRU. As this idea was beyond the scope of the master thesis we refrained from developing it further but it could be an interesting topic for further studies.

There could be several reasons for why our concept did not work, such as poorly presented or the use of video presentations of the concepts was not in its favour.

8.4.7 Statistical interpretation concerning results

The results from the tests are inferred with the aid from box plots. The average scores of valence and arousal are often misleading since we're mapping urgency to arousal. This is explained in detail in section 6.4.4. The complete data set is available on the homepage for closer inspection.

8.4.8 Proactive and reactive signals

The sounds associated with a bus today is a result of mechanical movement. The engine hum is a consequence of the power train. From a design perspective, that's great because you can hear how many revolution per minute the car or bus is doing, without looking at the dashboard. You can hear the acceleration without looking. The problem is when the sound is produced, which is last in the mechanical chain - it's reactive. When the roaring noise from the engine is issued it might already be too late, the VRU has already left the curb. The remedy to this can be artificial sound that can be triggered already when the driver steps on the gas pedal. In that sense artificial sound can be used to create proactive sounds which increases safety. The caveat is that the artificial sound is fake and only provide a model of the reality.

8.5 Further Work

In our master thesis the audio warning signals took over, relating to audio being a dominant sense. If we would have more time we would like to explore the visual factor to and see the results of that. We believe that our process and methods are applicable for visual warnings if such an investigation would be desired of Volvo Buses for another thesis concerning only the visual elements.

9

Conclusion

A exterior warning signal can be designed through a human centred and inclusive design perspective by utilising an action design research approach. The inclusive design perspective could potentially generate better designs by including it in the evaluation phases as well as the data gathering. While the multi-modality of the warning signal is important and probably beneficial, only the audio evaluation is enclosed in this report. However, the SAM-scale evaluation method can be reused for the visual signal as well as a multi-modal signal containing both visual and audio components, if a video prototype similar to the one we made is utilised.

Research Questions

We've shown that the designed audio warning signals are effective in a test situation but it remains to show how they perform in reality. It's also clear that we've received positive feedback from one of our key stakeholders Volvo Buses, but it remains to see if the feedback from bus drivers and vulnerable road users would be positive as well. The iterative design of visual warning signals lack a proper evaluation as they are only reviewed by ourself with input given from the expert Dennis Saluäär and feedback received from the monthly meetings with Volvo Buses.

The lack of evaluation stems from audio being the dominant modality as visual signals serves as an information carrier rather than a warning signal. We suggest that another master thesis is conducted with the aim to further design and evaluate visual warnings and audio signals with the SAM-scale.

By comparing all designed constant audio warning signals with each criterion of AVAS it was shown that none of the three warning signals fulfilled all requirements. It's notable that the failed criterion are subjective in contrast to the technical requirements. Technical issues was also the major concern raised by Volvo Buses, why a natural step would be to conduct tests in the traffic environment with a electric bus equipped with external speakers.

PEP-model

By iteration, reflection and abstraction the PEP-model was constructed. Three design concepts were built on its predecessor based on events and a platform procedure described in section 6.3.6 and 6.3.6. It serves as a tool to create coherent warning signals and describes how components are linked. The designed model conveys the mental model of a vehicle in cyclic operation, where a similar pattern is repeated with few exceptions which can be triggered in numerous ways. It remains to show how several PEP-models would be linked, serialised or used in parallel. Using several PEP-models in parallel could be a result of using many modalities, rather than using it to describe the complete warning signal as we did.

Evaluation Method

The SAM-scale can be utilised to measure the emotional arousal and valence of audio warning signals provided a context. The arousal can be mapped to a rank of urgency in order to assign a greater emotional arousal to a sound associated with a associated urgency. It would be desirable to use another evaluation method in combination with the SAM-scale in order to triangulate the emotional response and potentially troubleshoot the SAM-scale. Using additional evaluation methods might allow strengths and flaws of the current method to be revealed, which in turn can lead to a deeper understanding and further design improvements.

Design insights

As a result of the process, several findings are accidental or consequential. Relating to the inclusive design perspective, it was mainly present during the data gathering which was positive but not enough - as we lost it during the evaluation phases, mainly due to limited resources as it would require test participants from representative groups. Finding participants during the data gathering, through interviews, was feasible which led to great insights. It was also personally rewarding for us as authors. While making the prototypes we iterated through different mediums which impacted the designs to a surprisingly large extent. Finally, video prototypes was found to be very effective due to the temporal and spatial trade-off and high similarity to the actual environment.

Bibliography

Mark Allman-Ward, Roger Williams, Thorsten Heinz, and Maurizio Demontis. Designing and delivering the right sound for quiet vehicles. In *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*, volume 249, pages 4443–4451. Institute of Noise Control Engineering, 2014.

Penny Bergman, Anders Sköld, Daniel Västfjäll, and Niklas Fransson. Perceptual and emotional categorization of sound. *The Journal of the Acoustical Society of America*, 126(6):3156–3167, 2009.

Sheelagh Carpendale. *Sketching user experiences.* Elsevier/Morgan Kaufmann, Amsterdam Boston, 2012. ISBN 0123819598.

John Clarkson. *Inclusive design: Design for the whole population.* Springer Science & Business Media, 2003.

Allan Collins, Diana Joseph, and Katerine Bielaczyc. Design research: Theoretical and methodological issues. *The Journal of the learning sciences*, 13(1):15–42, 2004.

Alan Cooper. *About face : the essentials of interaction design.* John Wiley & Sons, Hoboken, 2014. ISBN 978-1118766576.

Judy Edworthy, Sarah Loxley, and Ian Dennis. Improving auditory warning design: Relationship between warning sound parameters and perceived urgency. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 33(2):205–231, 1991.

Judy Edworthy, Neville Stanton, and Elizabeth Hellier. Warnings in research and practice. *Ergonomics*, 38(11):2145–2154, 1995.

Steven F Fokkinga and Pieter MA Desmet. Ten ways to design for disgust, sadness, and other enjoyments: A design approach to enrich product experiences with negative emotions. *IJD International Journal of Design, 7 (1), 2013*, 2013.

Elizabeth Hellier and Judy Edworthy. On using psychophysical techniques to achieve urgency mapping in auditory warnings. *Applied Ergonomics*, 30(2):167–171, 1999.

Pertti Järvinen. Action research is similar to design science. *Quality & Quantity*, 41 (1):37–54, 2007. ISSN 0033-5177. doi: 10.1007/s11135-005-5427-1. URL `http://dx.doi.org/10.1007/s11135-005-5427-1`.

Tor Kihlman, Wolfgang Kropp, and William Lang. Quieter cities of the future. Technical report, Technical Report, International Institute of Noise Control Engineering, CAETS, 2014.

Hanna Ljungblad and Torunn Renhammar. Tystare stadsbussar: kravställning vid upphandling för minskat källbuller, November 11 2013. Koucky & Partners AB på uppdrag av Trafikverket.

Jonas Löwgren. *Thoughtful interaction design a design perspective on information technology.* MIT Press, Cambridge, Mass, 2004. ISBN 9780262622097.

John Maeda. *The laws of simplicity.* MIT press, 2006.

Salvatore T March and Gerald F Smith. Design and natural science research on information technology. *Decision support systems*, 15(4):251–266, 1995.

Nicolas Misdariis and Andrea Cera. Sound signature of quiet vehicles: state of the art and experience feedbacks. In *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*, volume 247, pages 3333–3342. Institute of Noise Control Engineering, 2013.

Michael Myers. Investigating information systems with ethnographic research. *Commun. AIS*, 2(4es), December 1999. URL `http://dl.acm.org/citation.cfm?id=374486.374487`.

Roy D Patterson and Civil Aviation Authority. *Guidelines for auditory warning systems on civil aircraft.* Civil Aviation Authority, 1982.

Jenny Preece, Helen Sharp, and Yvonne Rogers. *Interaction Design-beyond human-computer interaction.* John Wiley & Sons, 2015.

Ulf Sandberg, Luc Goubert, and Piotr Mioduszewski. Are vehicles driven in electric mode so quiet that they need acoustic warning signals. In *20th International Congress on Acoustics*, 2010.

Ulf Sangberg. Adding noise to quiet electric and hybrid vehicels: An electric issue. *Noise News International*, 20(2):51–67, 2012.

Nadine Schaeffer. User stories, scenarios & use cases, 2011. URL `http://www.cloudforestdesign.com/2011/04/25/introduction-user-stories-user-personas-use-cases-whats-the-difference/`.

Maung Sein, Ola Henfridsson, Sandeep Purao, Matti Rossi, and Rikard Lindgren. Action design research. 2011.

Edward Steinfeld and Jordana Maisel. *Universal design: Creating inclusive environments.* John Wiley & Sons, 2012.

Human Centered Design Toolkit. Ideo. *Retrieved on 24th November*, 2008.

Y Wadsworth. Do it yourself social research, 2nd ednallen & unwin, 1997.

Yoland Wadsworth. *Do it yourself social research.* Allen & Unwin, Crows Nest, N.S.W, 2011. ISBN 9781742370637.

Michael S Wogalter, Vincent C Conzola, and Tonya L Smith-Jackson. Research-based guidelines for warning design and evaluation. *Applied ergonomics*, 33(3):219–230, 2002.

Appendices

A

Audio test

A.1 Results

Below is a summary of all the results in two separate tables. The first table in A.1.1concern the arousal parameter and the second A.1.2 the valence parameter.

A.1.1 Arousal

Arousal

Test case	Sound	Data					
		Samples	(Min/Max)	Mean	Variance	Skewness	Kurtosis
A							
	Sound 1	18	(1, 3)	1.72	0.33	0.02	-0.51
	Sound 2	18	(2, 5)	3.78	0.54	-0.58	0.46
	Sound 3	18	(1, 5)	2.33	1.18	0.44	0.06
AB							
	Sound 1	18	(1, 5)	3.39	0.72	-0.83	1.83
	Sound 2	18	(1, 4)	2.61	1.08	-0.47	-0.92
	Sound 3	18	(1, 5)	4.00	1.29	-1.23	0.94
C							
	Sound 1	18	(1, 5)	3.50	1.09	-0.80	0.16

	Sound 2	18	(2, 4)	2.94	0.53	0.08	-0.99
	Sound 3	18	(1, 4)	2.78	0.65	-0.27	-0.30
DE							
	Sound 1	18	(1, 5)	3.44	0.97	-0.60	0.51
	Sound 2	18	(1, 5)	3.33	0.94	-0.71	0.19
	Sound 3	18	(2, 5)	3.28	1.15	0.01	-1.34
	Sound 4	18	(1, 4)	2.44	0.97	-0.22	-1.00
	Sound 5	18	(2, 5)	3.22	0.89	0.41	-0.60
F							
	Sound 1	18	(1, 4)	2.22	0.54	0.58	0.46
	Sound 2	18	(2, 5)	3.28	0.80	-0.06	-0.92
	Sound 3	18	(2, 5)	3.33	0.82	-0.22	-0.98
	Sound 4	18	(1, 5)	3.00	0.71	0.00	1.50
AG							
	Sound 1	18	(1, 5)	3.39	0.72	-0.83	1.83
	Sound 2	18	(1, 4)	2.61	1.08	-0.47	-0.92
	Sound 3	18	(1, 5)	4.00	1.29	-1.23	0.94
H							
	Sound 1	18	(3, 5)	4.06	0.53	-0.08	-0.99
	Sound 2	18	(1, 5)	3.11	0.81	-0.22	0.62
	Sound 3	18	(2, 5)	3.67	0.71	0.07	-0.67
	Sound 4	18	(3, 5)	3.78	0.54	0.35	-0.99

Table A.1: Summary statistics of the Arousal parameter for all audio warning signals included in the SAM-scale evaluation.

A.1.2 Valence

		Valence					
Test case	Sound	Data					
		Samples	(Min/Max)	Mean	Variance	Skewness	Kurtosis
A							

	Sound 1	18	(2, 5)	3.11	0.93	0.59	-0.47
	Sound 2	18	(1, 3)	1.78	0.65	0.41	-1.27
	Sound 3	18	(2, 5)	3.28	0.80	-0.06	-0.92
AB							
	Sound 1	18	(2, 5)	3.06	0.53	0.87	1.41
	Sound 2	18	(2, 5)	3.83	0.38	-1.45	3.02
	Sound 3	18	(1, 5)	2.11	1.16	0.93	0.77
C							
	Sound 1	18	(2, 5)	4.17	0.85	-0.79	-0.31
	Sound 2	18	(2, 5)	3.39	0.96	0.32	-0.82
	Sound 3	18	(1, 4)	2.33	0.59	0.18	-0.24
DE							
	Sound 1	18	(3, 5)	3.89	0.58	0.18	-1.15
	Sound 2	18	(3, 5)	3.83	0.62	0.29	-1.24
	Sound 3	18	(1, 5)	2.28	0.80	1.46	2.97
	Sound 4	18	(1, 4)	2.56	0.61	-0.56	-0.21
	Sound 5	18	(2, 5)	3.83	0.62	-0.46	0.07
F							
	Sound 1	18	(1, 5)	3.22	1.12	-0.15	-0.39
	Sound 2	18	(2, 5)	3.72	0.68	-0.74	0.18
	Sound 3	18	(1, 5)	2.94	1.58	-0.08	-1.46
	Sound 4	18	(1, 5)	3.50	0.97	-0.76	0.64
AG							
	Sound 1	18	(2, 5)	3.06	0.53	0.87	1.41
	Sound 2	18	(2, 5)	3.83	0.38	-1.45	3.02
	Sound 3	18	(1, 5)	2.11	1.16	0.93	0.77
H							
	Sound 1	18	(2, 5)	3.00	0.82	0.49	-0.61
	Sound 2	18	(1, 5)	2.44	1.56	0.78	-0.19
	Sound 3	18	(2, 5)	3.44	0.61	-0.19	-0.43
	Sound 4	18	(1, 5)	3.44	1.56	-0.34	-1.01

Table A.2: Summary statistics of the Valence parameter for all audio warning signals included in the SAM-scale evaluation.

A.2 Material used for audio test

The user test consent form, introduction to user test and user test initial questions below was given to every participant in the audio test.

USER TEST CONSENT FORM

Please read and sign this form!

This test is divided in two parts. It will include:
- You will be asked to measure level of sound regarding different aspects.
- We will conduct an interview where we talk about what happened in the test.

Participation in this study is voluntarily. All content in this test is confidential, but your information and opinions will be used to evaluate the sounds and material used during the test. No names or other type of identification will be used and you are free to leave the study whenever you feel like it.

If you have any questions after this study is done, feel free to contact us at:
idaha@student.chalmers.se or karlbe@student.chalmers.se

Name: ____________________ Age: _____________ Gender: ________________

Date: ____________ Signature: ____

INTRODUCTION TO USER TEST

Vi gör ett exjobb åt Volvo Bussar och i det här testet så kommer vi utvärdera olika ljud till olika tänkbara situationer för bussen. Vad vi vill ha hjälp med är dina personliga åsikter om hur du uppfattar de olika ljuden. Det finns inga rätt och fel och att bedöma ljud är väldigt svårt. Vad vi är ute efter är din spontana reaktion på de olika ljuden.

Vi kommer använda oss av en känslomässig skala med två olika faktorer. Fösta faktorn handlar om hur du upplever ljudet, upplever du olust eller behag? Den andra faktorn handlar om hur du reagerar på ljudet, blir du lugn eller aktiverad?

Vi kommer att visa 6 olika filmklipp. Varje filmklipp består av flera antal ljud, det är dessa du ska bedöma genom att markera den bild som återspeglar din reaktion bäst. När vi har gått genom alla ljud får du se filmen igen och ändra dina svar om du så vill.

Figure A.1: The consent form that was filled in by all user testers along with the manuscript to introduce the testers of the test.

USER TEST INITIAL QUESTIONS

How often do you travel by bus?

- ☐ Every day
- ☐ Every week
- ☐ Every month
- ☐ Every year
- ☐ Never

What is the main purpose of your travel with bus?

____

____

What is your relationship to the new electric bus named 55.

- ☐ Have never heard about it
- ☐ Have heard about it
- ☐ Have traveled with it
- ☐ Have worked with it

How often do you travel with the electric bus 55?

- ☐ Every day
- ☐ Every week
- ☐ Every month
- ☐ Every year
- ☐ Never

Comments

____

____

Figure A.2: The initial questions filled in by all user testers.

A.3 Score sheet used in audio test

The score sheet used for documenting test persons data.

SHEET FOR RECORDING ANSWERS

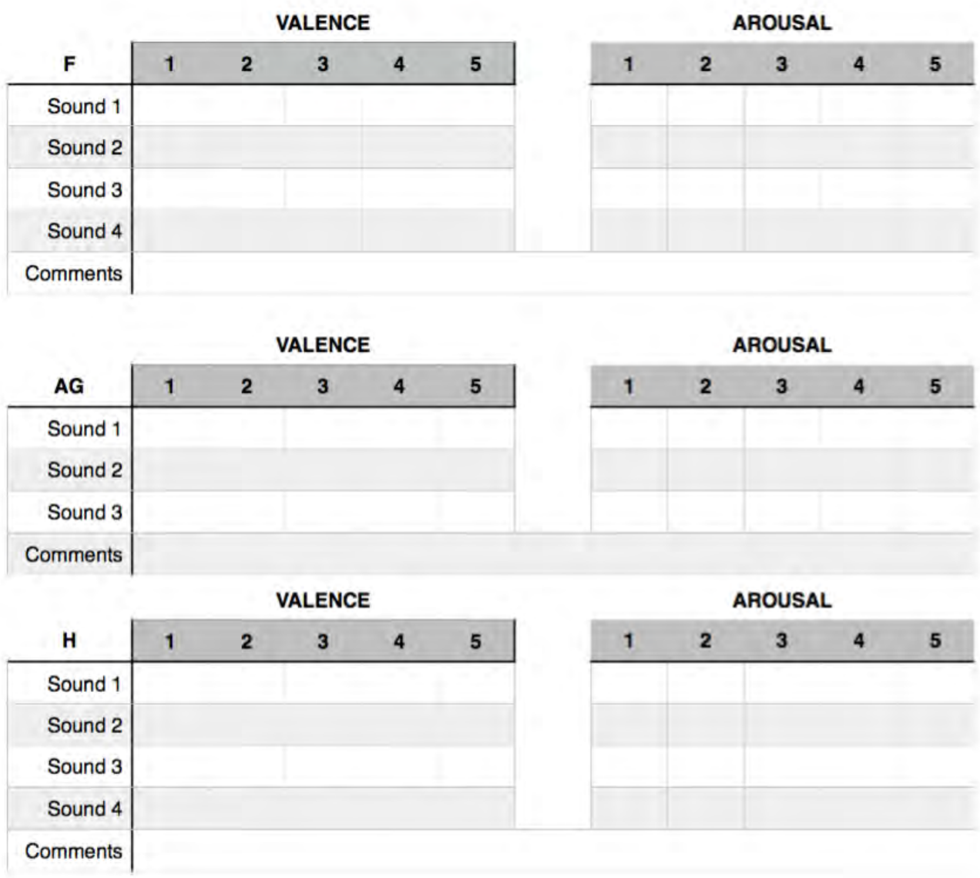
	VALENCE					AROUSAL				
A	1	2	3	4	5	1	2	3	4	5
Sound 1										
Sound 2										
Sound 3										
Comments										

	VALENCE					AROUSAL				
AB	1	2	3	4	5	1	2	3	4	5
Sound 1										
Sound 2										
Sound 3										
Comments										

	VALENCE					AROUSAL				
C	1	2	3	4	5	1	2	3	4	5
Sound 1										
Sound 2										
Sound 3										
Comments										

	VALENCE					AROUSAL				
DE	1	2	3	4	5	1	2	3	4	5
Sound 1										
Sound 2										
Sound 3										
Sound 4										
Sound 5										
Comments										

Figure A.3: Score sheet used in audio test to record answers.



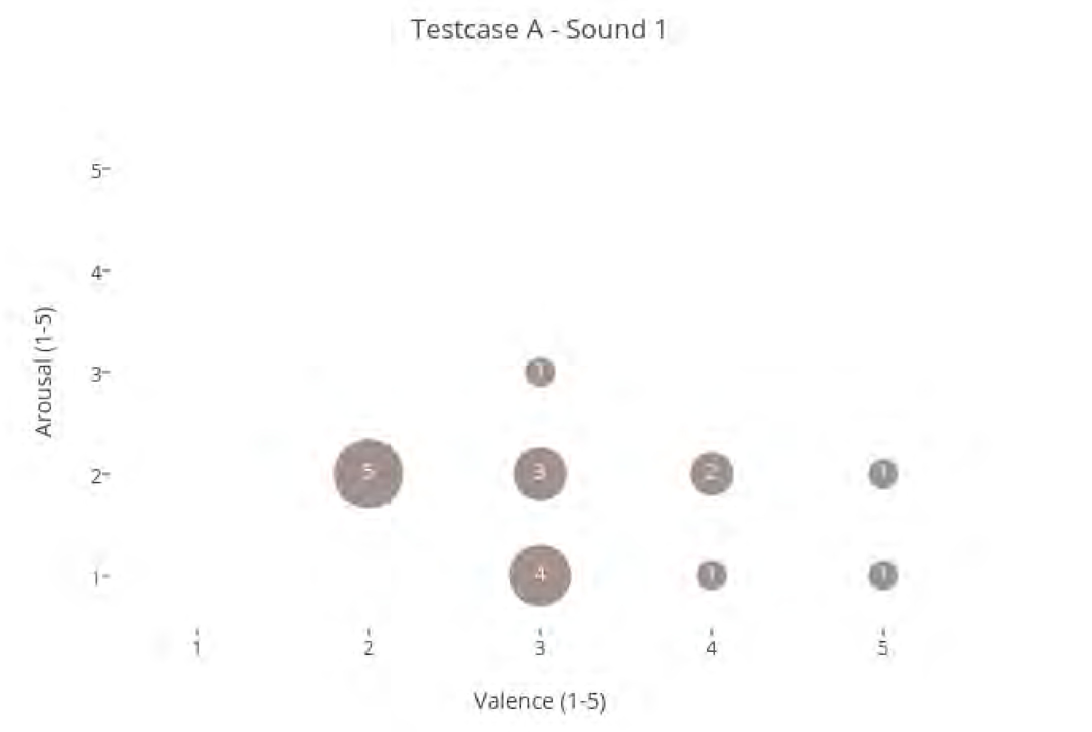
	VALENCE					AROUSAL				
F	1	2	3	4	5	1	2	3	4	5
Sound 1										
Sound 2										
Sound 3										
Sound 4										
Comments										

	VALENCE					AROUSAL				
AG	1	2	3	4	5	1	2	3	4	5
Sound 1										
Sound 2										
Sound 3										
Comments										

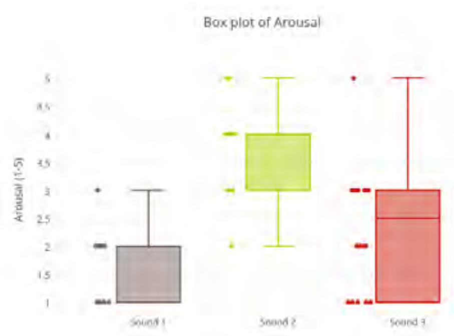
	VALENCE					AROUSAL				
H	1	2	3	4	5	1	2	3	4	5
Sound 1										
Sound 2										
Sound 3										
Sound 4										
Comments										

Figure A.4: Score sheet used in audio test to record answers.

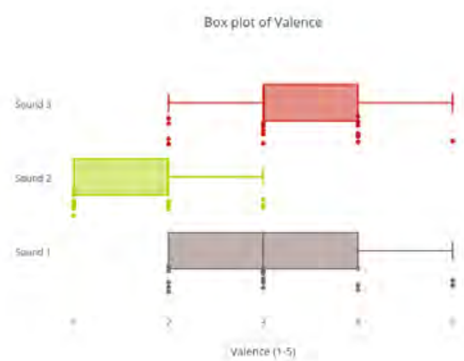
A.4 Results of sounds excluded in the final concept



(a) Shows a scatter plot of Sound 1 for test case A. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

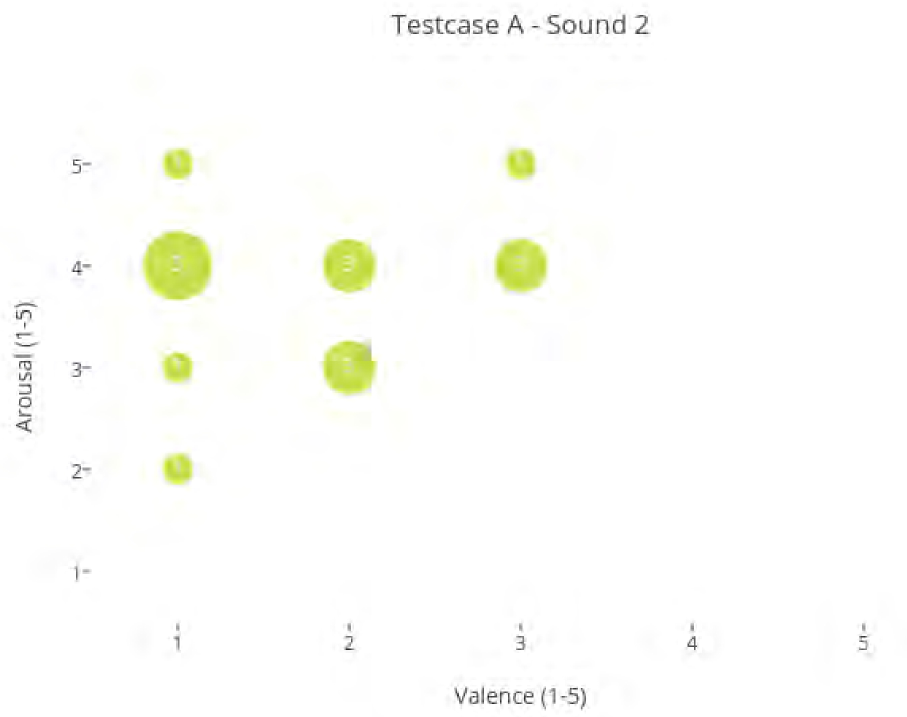


(b) The arousal parameter summarized by box plots for each sound in the test case.

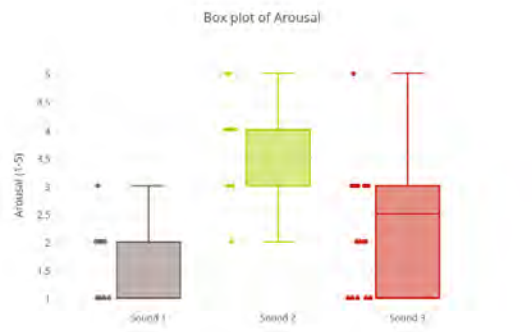


(c) The valence parameter summarized by box plots for each sound in the test case.

Figure A.5: The test answers for case A. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



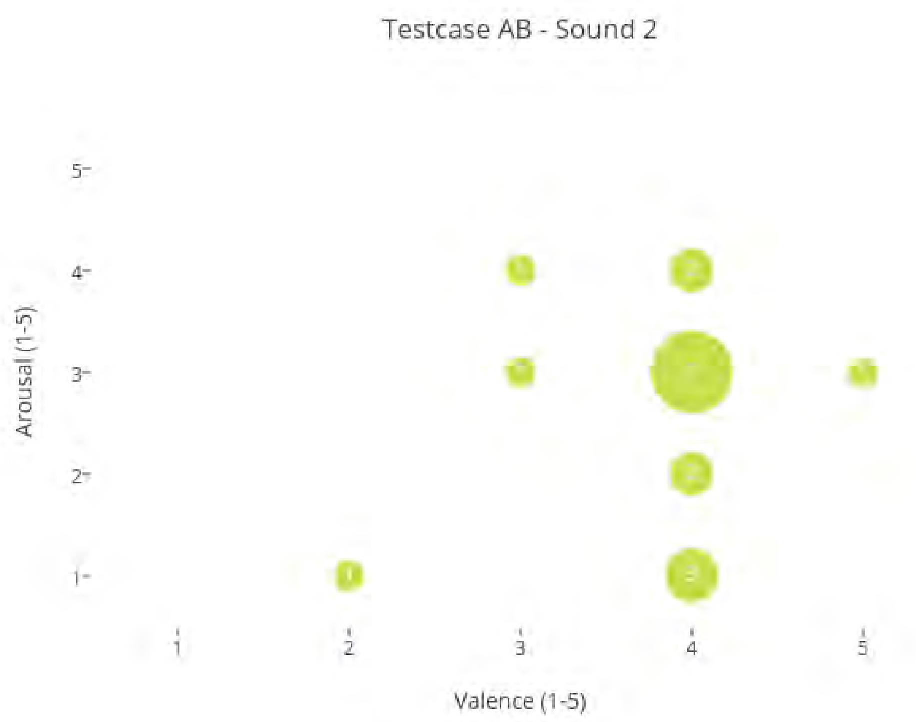
(a) Shows a scatter plot of Sound 2 for test case A. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



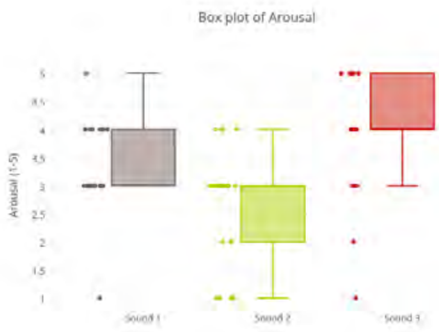
(b) The arousal parameter summarized by box plots for each sound in the test case.

(c) The valence parameter summarized by box plots for each sound in the test case.

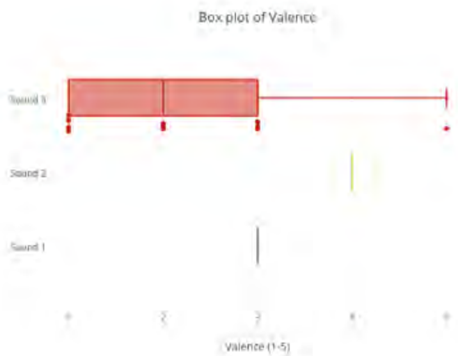
Figure A.6: The test answers for case A. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 2 for test case AB. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

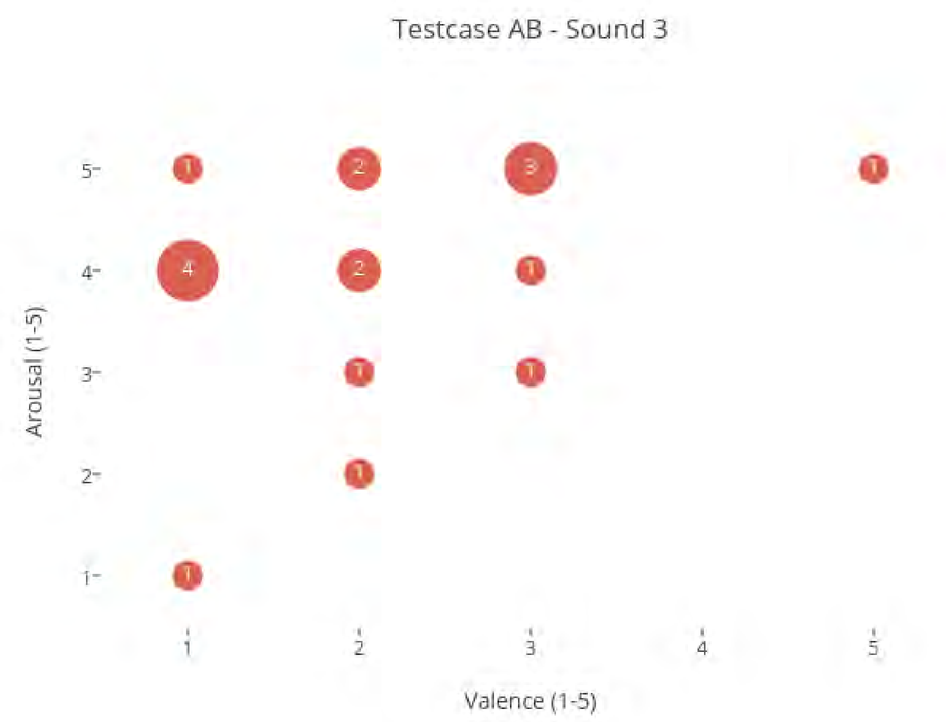


(b) The arousal parameter summarized by box plots for each sound in the test case.

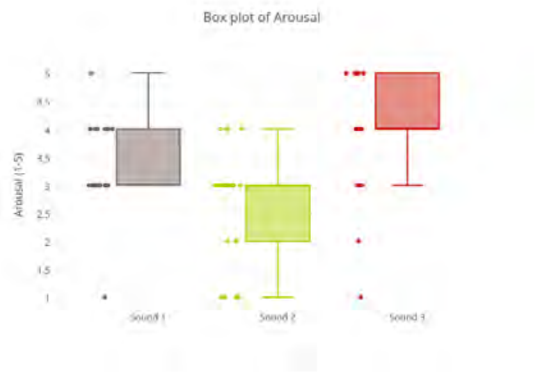


(c) The valence parameter summarized by box plots for each sound in the test case.

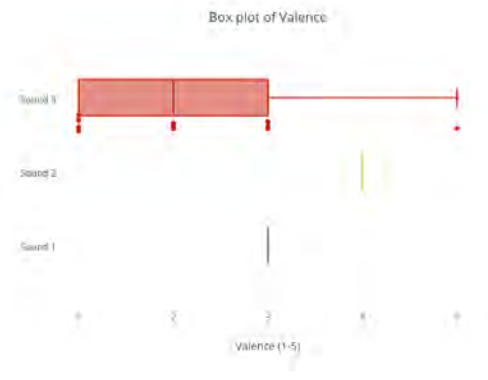
Figure A.7: The test answers for case AB. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 3 for test case AB. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

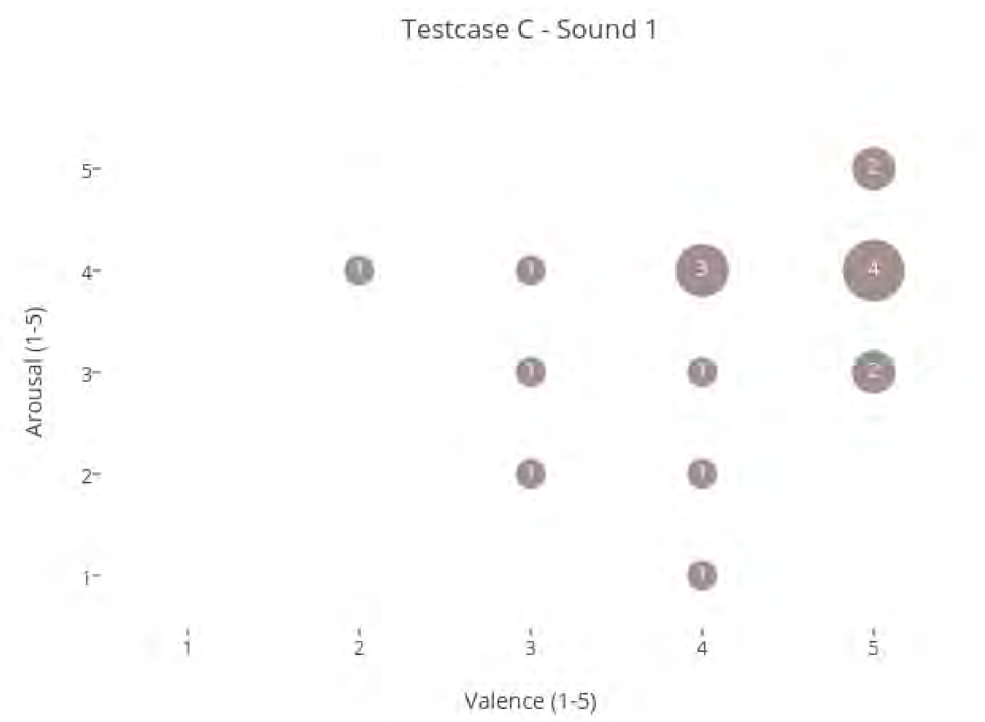


(b) The arousal parameter summarized by box plots for each sound in the test case.

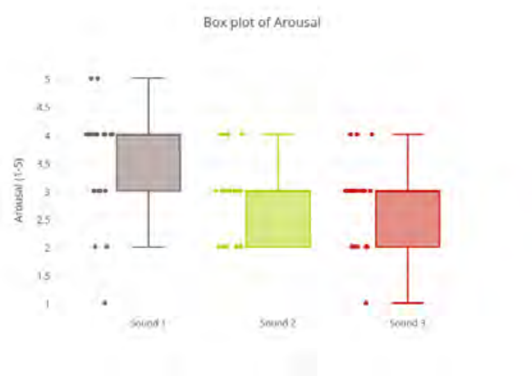


(c) The valence parameter summarized by box plots for each sound in the test case.

Figure A.8: The test answers for case AB. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



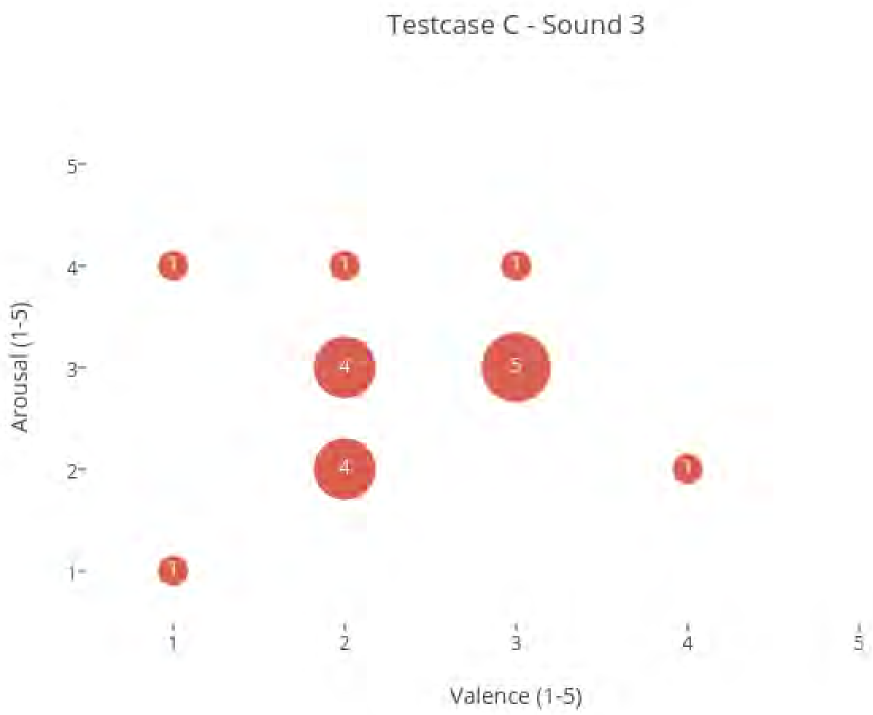
(a) Shows a scatter plot of Sound 1 for test case C. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



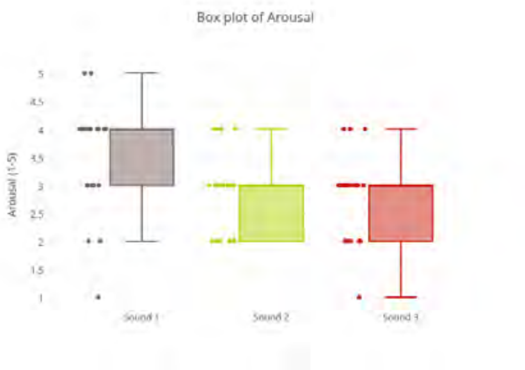
(b) The arousal parameter summarized by box plots for each sound in the test case.

(c) The valence parameter summarized by box plots for each sound in the test case.

Figure A.9: The test answers for case C. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



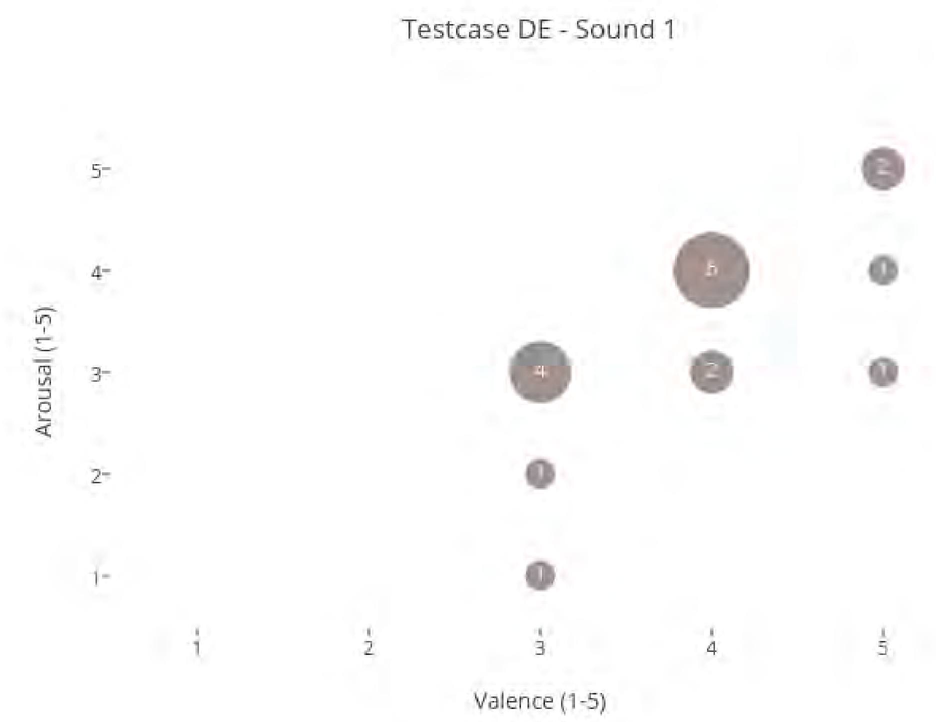
(a) Shows a scatter plot of Sound 3 for test case C. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



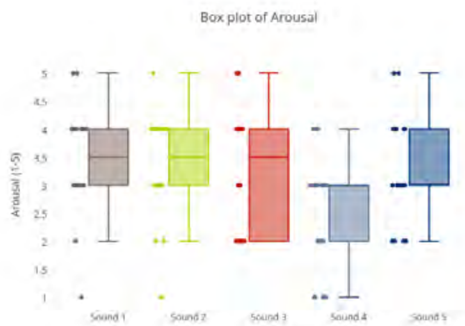
(b) The arousal parameter summarized by box plots for each sound in the test case.

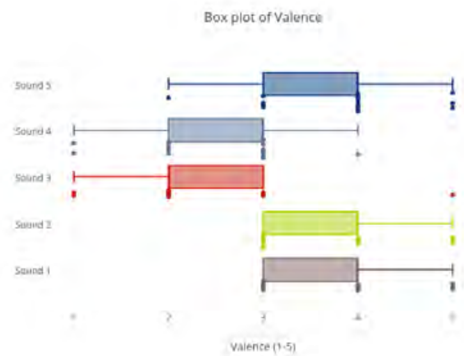
(c) The valence parameter summarized by box plots for each sound in the test case.

Figure A.10: The test answers for case C. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 1 for test case DE. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

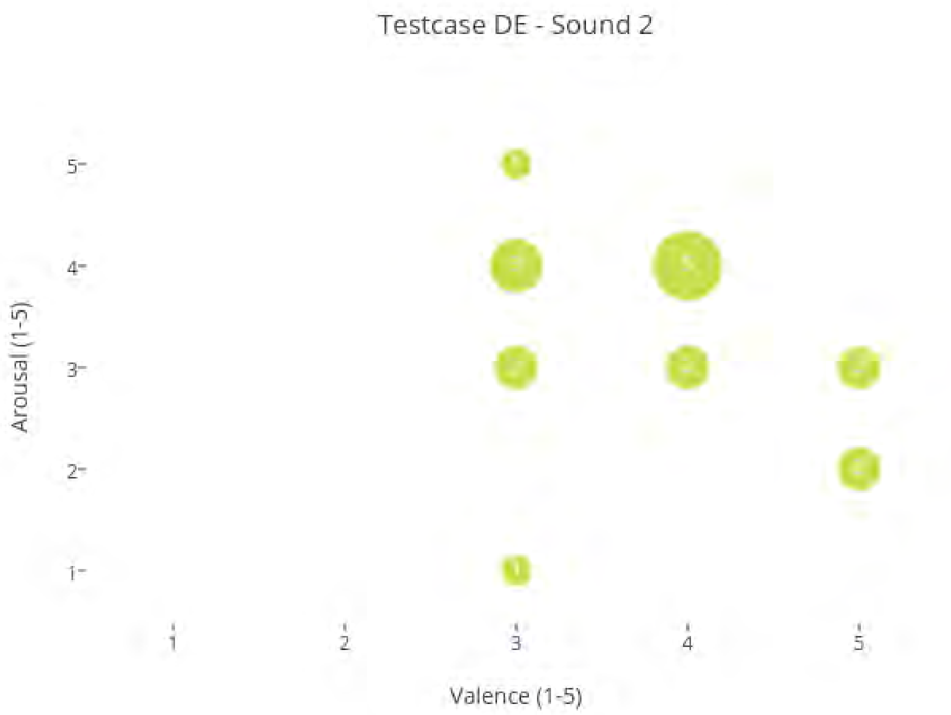




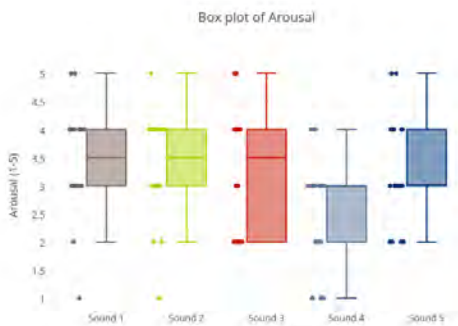
(b) The arousal parameter summarized by box plots for each sound in the test case.

(c) The valence parameter summarized by box plots for each sound in the test case.

Figure A.11: The test answers for case DE. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



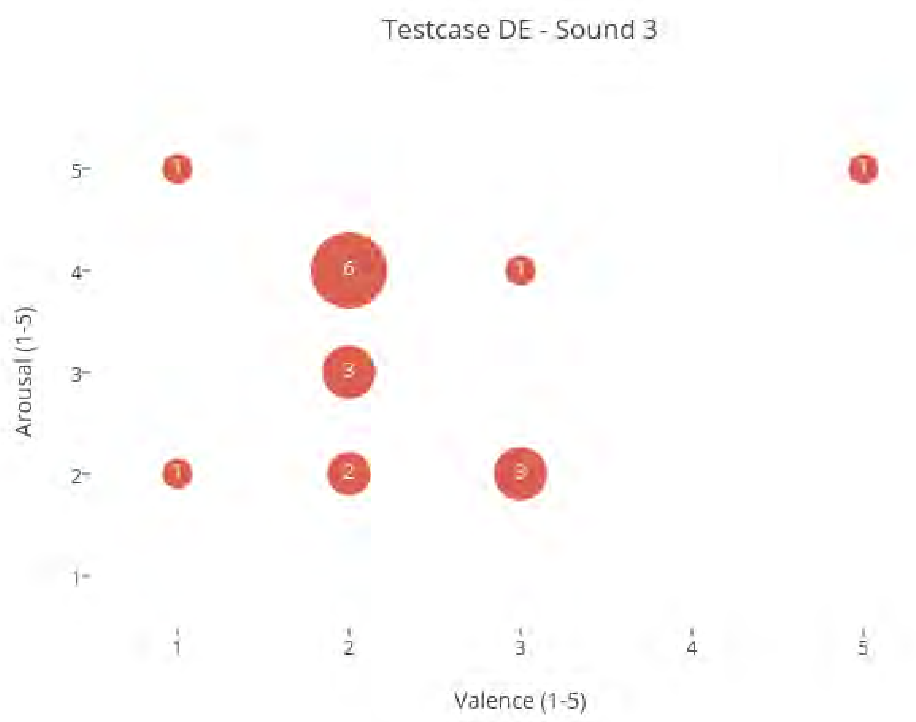
(a) Shows a scatter plot of Sound 2 for test case DE. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



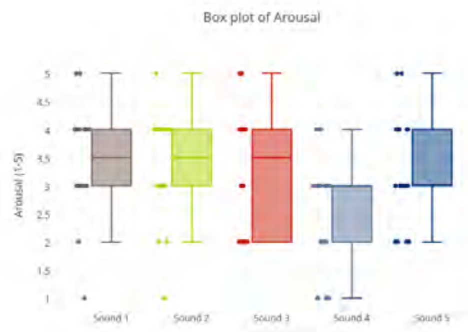
(b) The arousal parameter summarized by box plots for each sound in the test case.

(c) The valence parameter summarized by box plots for each sound in the test case.

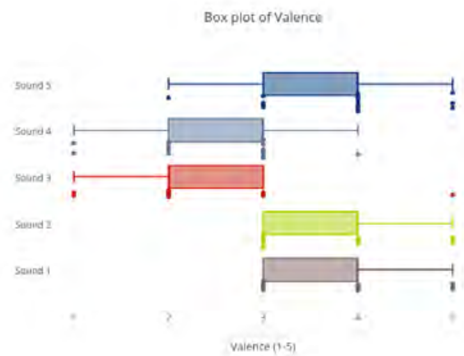
Figure A.12: The test answers for case DE. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 3 for test case DE. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

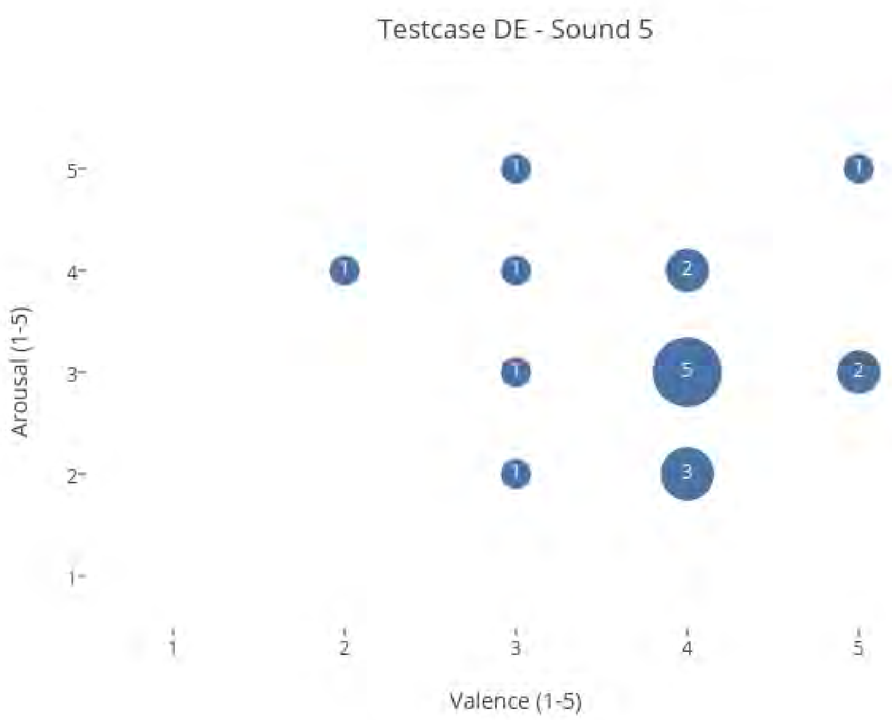


(b) The arousal parameter summarized by box plots for each sound in the test case.

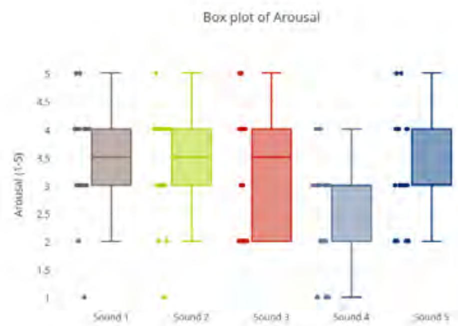


(c) The valence parameter summarized by box plots for each sound in the test case.

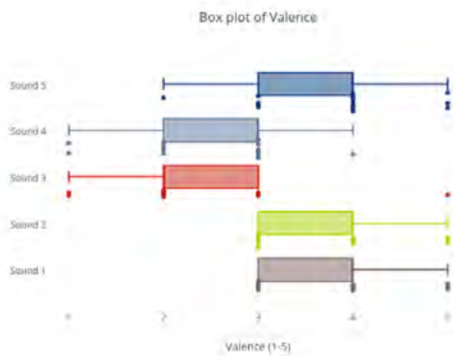
Figure A.13: The test answers for case DE. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 5 for test case DE. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

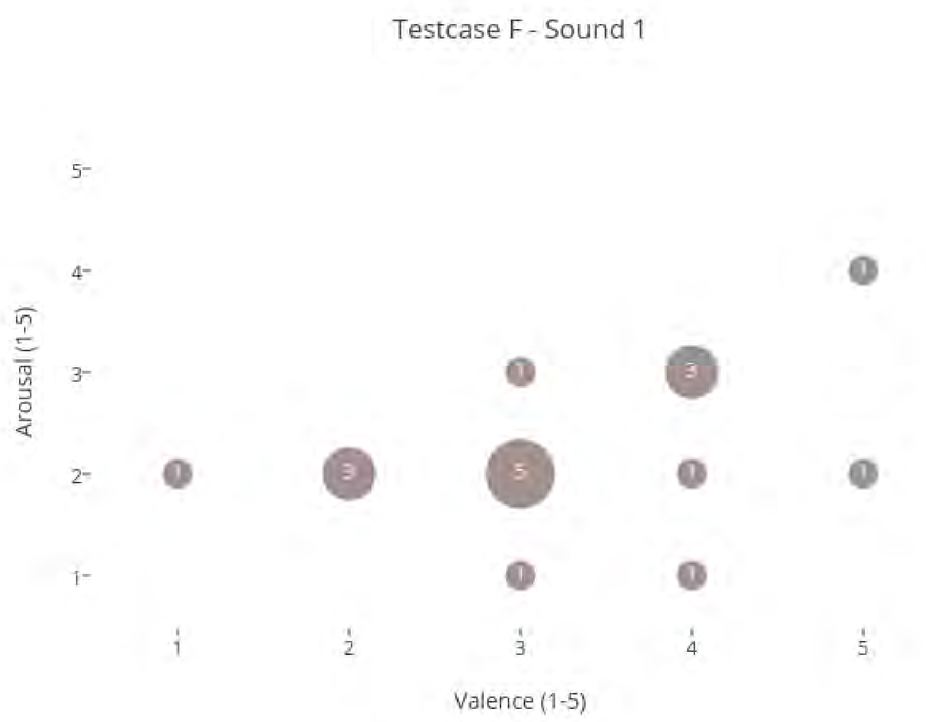


(b) The arousal parameter summarized by box plots for each sound in the test case.

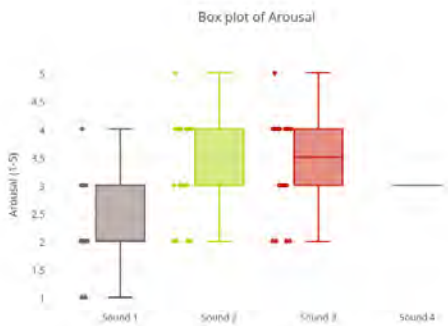


(c) The valence parameter summarized by box plots for each sound in the test case.

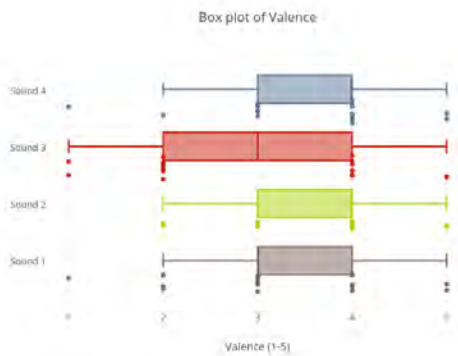
Figure A.14: The test answers for case DE. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 1 for test case F. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

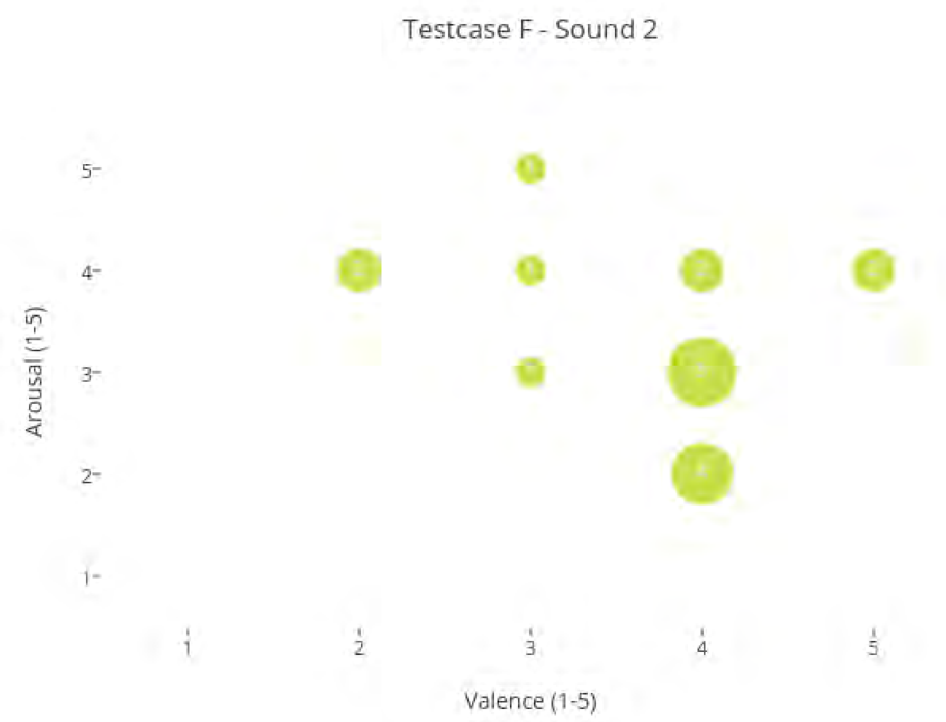


(b) The arousal parameter summarized by box plots for each sound in the test case.

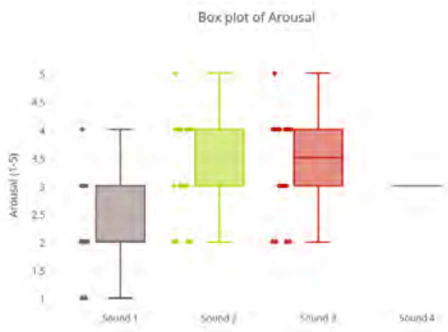


(c) The valence parameter summarized by box plots for each sound in the test case.

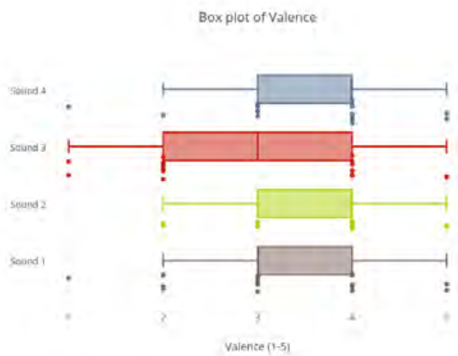
Figure A.15: The test answers for case F. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 2 for test case F. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

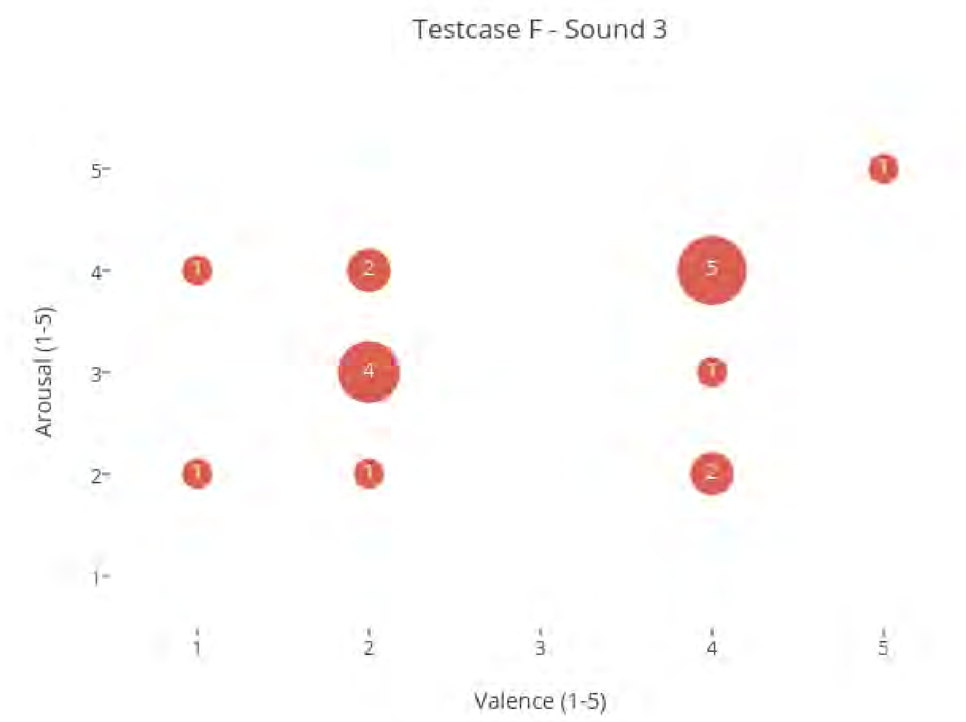


(b) The arousal parameter summarized by box plots for each sound in the test case.

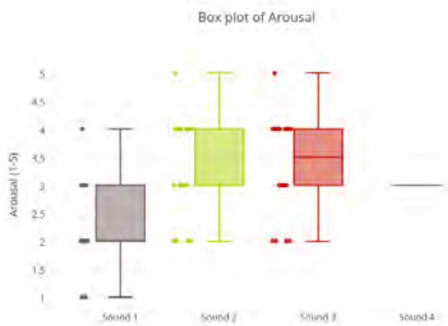


(c) The valence parameter summarized by box plots for each sound in the test case.

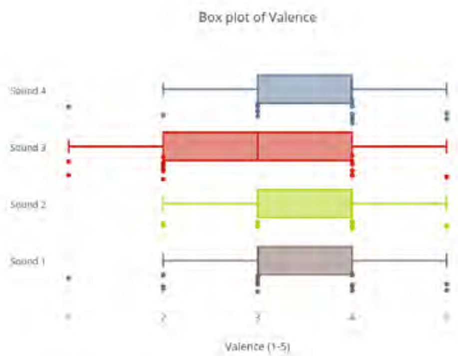
Figure A.16: The test answers for case F. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 3 for test case F. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

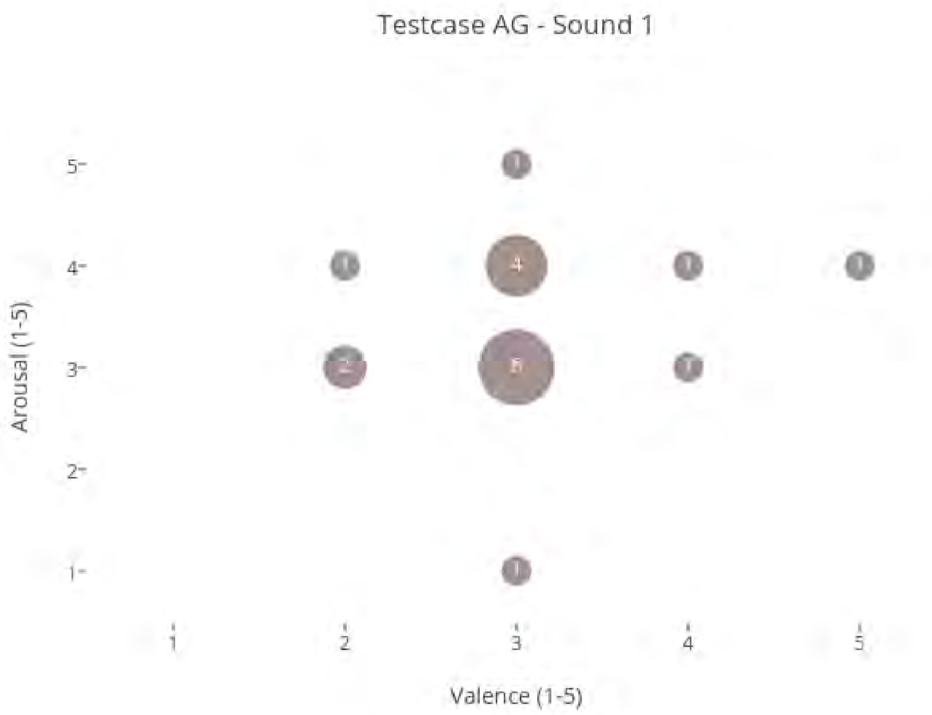


(b) The arousal parameter summarized by box plots for each sound in the test case.

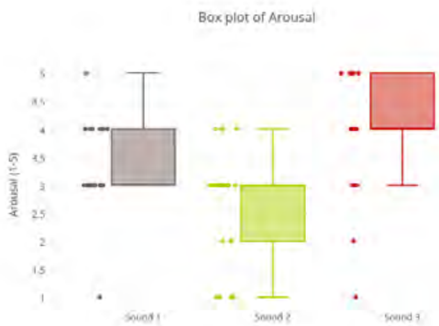


(c) The valence parameter summarized by box plots for each sound in the test case.

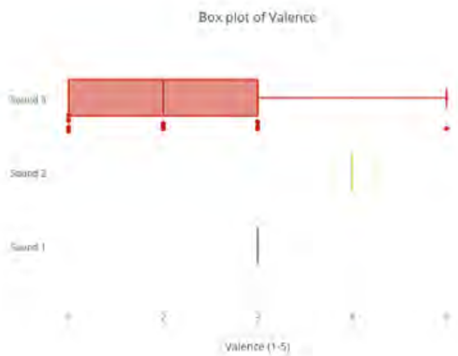
Figure A.17: The test answers for case F. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 1 for test case AG. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

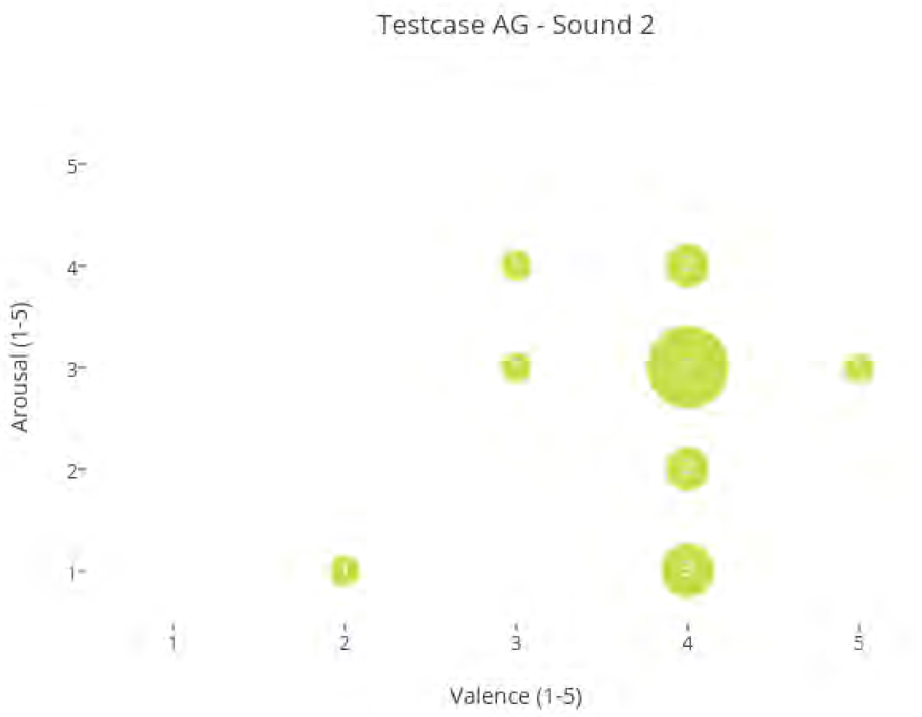


(b) The arousal parameter summarized by box plots for each sound in the test case.

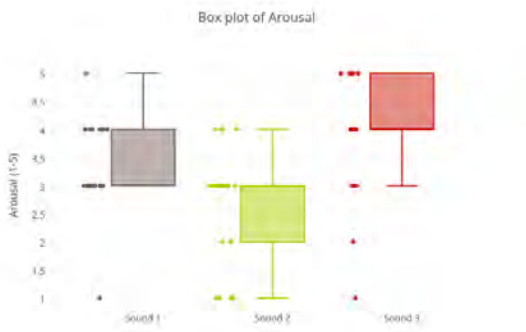


(c) The valence parameter summarized by box plots for each sound in the test case.

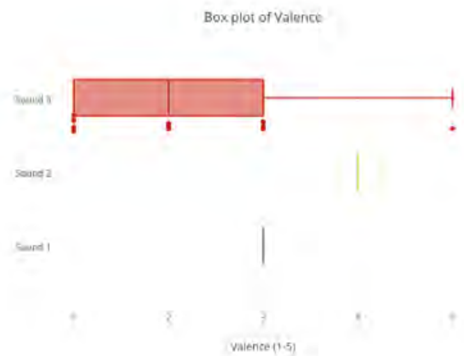
Figure A.18: The test answers for case AG. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 2 for test case AG. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

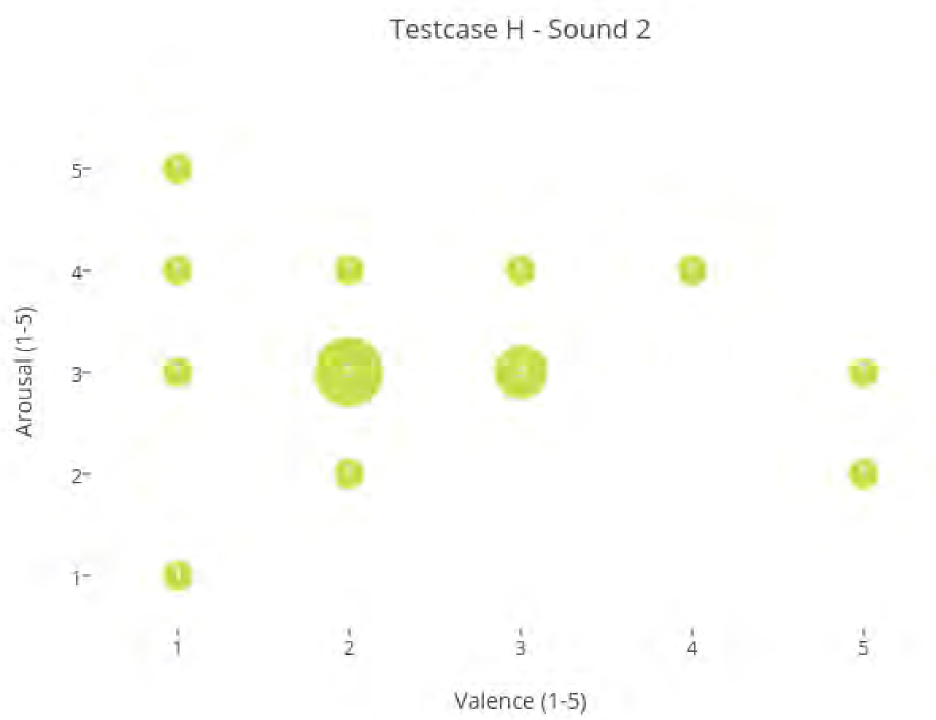


(b) The arousal parameter summarized by box plots for each sound in the test case.

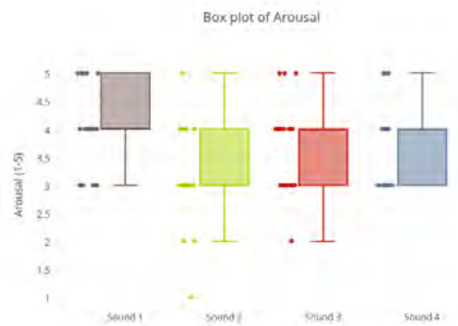


(c) The valence parameter summarized by box plots for each sound in the test case.

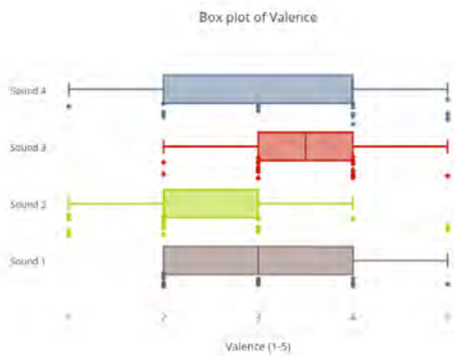
Figure A.19: The test answers for case AG. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 2 for test case H. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

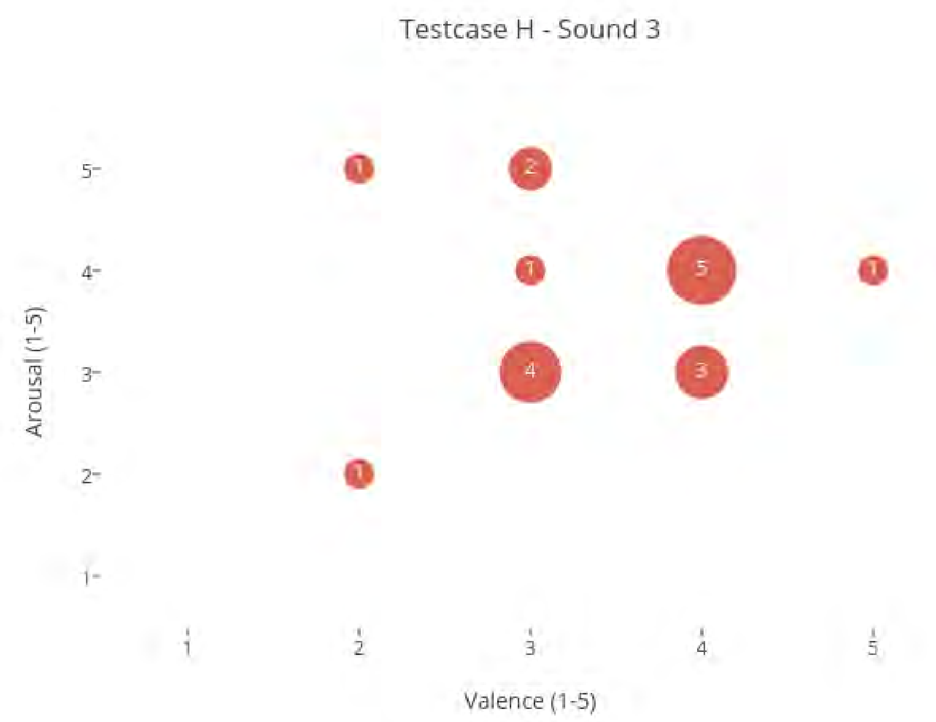


(b) The arousal parameter summarized by box plots for each sound in the test case.

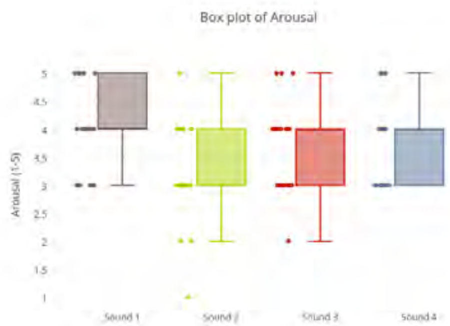


(c) The valence parameter summarized by box plots for each sound in the test case.

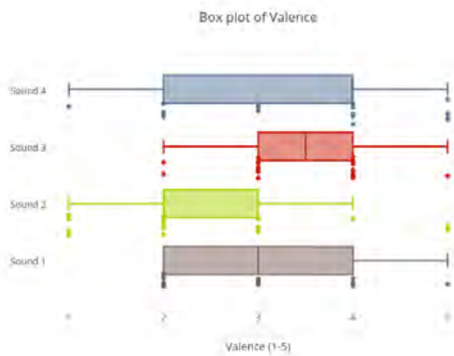
Figure A.20: The test answers for case H. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 3 for test case H. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful

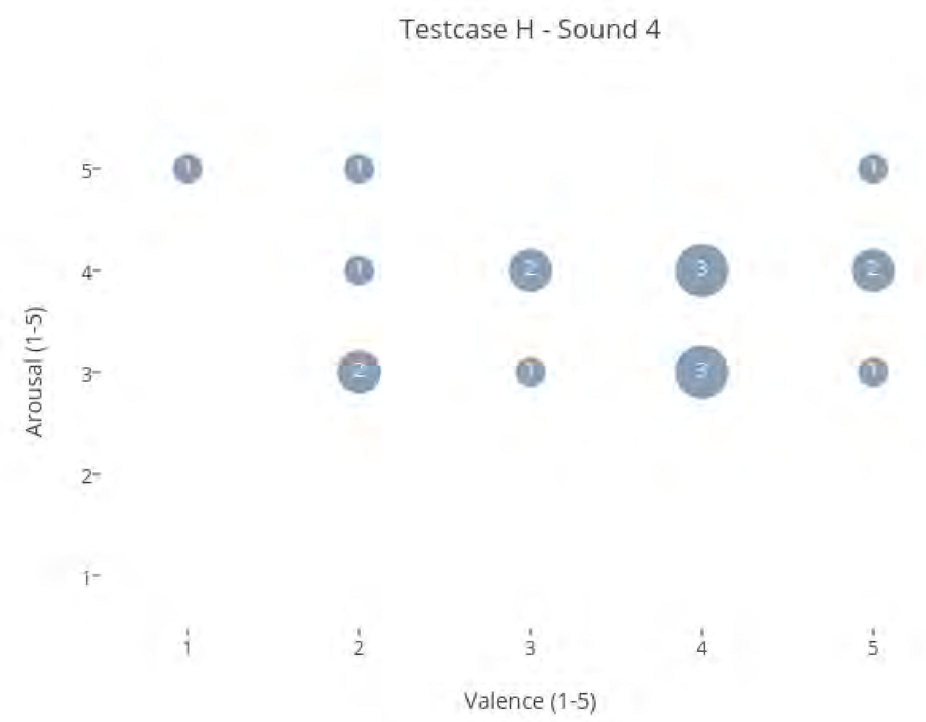


(b) The arousal parameter summarized by box plots for each sound in the test case.

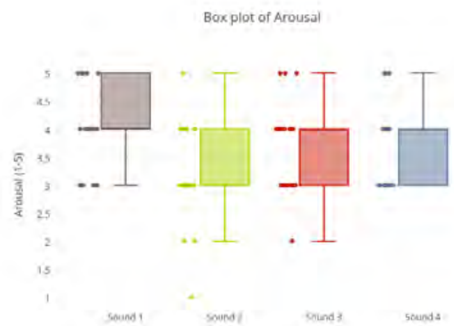


(c) The valence parameter summarized by box plots for each sound in the test case.

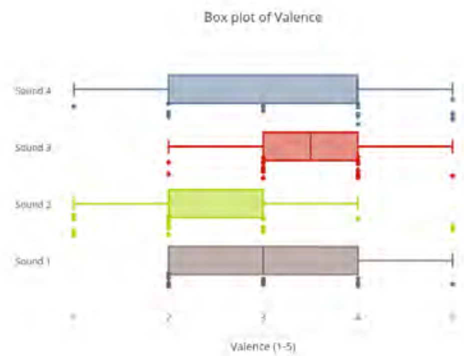
Figure A.21: The test answers for case H. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.



(a) Shows a scatter plot of Sound 4 for test case H. In order to show duplicate values the size of the data point is increased. Thus, the size of a data point is proportional to the frequency. The arousal is given on a scale from 1 to 5, where 1 is Calm and 5 is Active. The valence is given on a scale from 1 to 5, where 1 is Sad and 5 is Joyful



(b) The arousal parameter summarized by box plots for each sound in the test case.



(c) The valence parameter summarized by box plots for each sound in the test case.

Figure A.22: The test answers for case H. The answers are given in terms of the SAM-scale which consists of two parameters: Arousal (given by the y-axis) and Valence given by the (x-axis). The scatter plot is supported with box plots of all the sounds in the test case in order to provide context.

B

Interviews

Below follows interview questions for the semi-structured interviews.

B.1 Interview with bus drivers

INTERVJUFRÅGOR TILL BUSSCHAUFFÖR

Introduktion, vilka är vi?
Vi är masterstudenter från Chalmers som är här på Volvo Bussar och genomför vårt examensarbete om elektriska bussars varningssignaler. Vi är här idag för att bekanta oss med de nya bussarna men också för att få en bättre inblick i yrket som busschaufför.

..och vem är du?
- Hur länge har du varit busschaufför?
- Vad har du för erfarenhet av el-bussar?
- Vad är den största skillnaden på en vanlig buss och en el-buss som förare?

På hållplatsen
- Finns det någon situation som känns extra farlig? Vad händer, och vart?
- Hur reagerar trafikanter på Tuta/Pling/Hållplats-klockan?
- Tutar du på passagerare? Hur ofta och när? Varför?
- Upplever du att många trafikanter rör sig nära bussen? När, Varför?
- Vilken hållplats är värst?

Ljudlöst
- Saknar du ljudet?
- Finns det någon situation där ljud är högst nödvändigt? Vilken?
- Vad anser du om säkerhetsaspekten med el-bussar?
    - Ingång/Utgång
    - Passerar framför bussen
    - Bussen svänger
    - Hållplats
    - Buss startar och stoppar

Avslutningsvis
- Hur mycket påverkas din arbetsmiljön av trafikanter?
- Kan bättre varningssignaler förbättra din arbetsmiljö?
- Har du en uppfattning om hur det står sig gentemot el-bussens ljud?

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Figure B.1: Interview questions

B.2 Interview with SRF, HRF and FSDB

INTERVJUFRÅGOR TILL FSDB, SRF OCH HRF

Vi läser Interaktionsdesign på Chalmers vilket handlar om att man ska designa tekniken efter människan istället för att låta tekniken bestämma, och människan anpassa sig efter tekniken. Just nu håller vi på med vårt Masterarbete som är det sista vi gör innan vi får vår examen och det här gör vi i samarbete med Volvo bussar. Uppgiften är att försöka ta reda på hur vi ska utrusta bussar med varningar så att de blir så effektiva som möjligt och kan uppfattas av alla.

- Fråga 1 - Vad innebär det att vara dövblind/synskadad/hörselskadad? (Har ni varit sedan födsel eller när kom det?)
- Fråga 2 - Hur är det att resa med kollektivtrafiken idag?
- Fråga 3 - Reser ni i dagsläget med kollektivtrafiken, varför/varför inte?
- Fråga 4 - Vistas i trafik?
- Fråga 5 - Hur upplever ni varningssignaler i staden idag? Övergångsställen, Hållplatser, Fordon
- Fråga 6 - Finns det några exempel på varningssignaler i andra sammanhang som ni tycker är dåliga?
- Fråga 7 - Finns det några exempel på varningssignaler i andra sammanhang som ni tycker är bra?
- Fråga 8 - Som dövblind/synskadad/hörselskadad, innebär det att man måste förlita sig mer på ljussignaler/ljussignaler
- Fråga 9 - Vad finns det för speciell utrustning som kan underlätta en dövblind/synskadad/hörselskadads vardag?
- Fråga 10 - Vad finns det för speciell utrustning som kan underlätta att uppfatta ljud/ljussignaler?

Här efter introduceras ämnet inkluderande design och hur vi arbetar kring det. Eventuellt visa en bild på tjejen som går med mobil och hörlurar i trafiken. Avsikten med det här är att öppna upp diskussion om ämnet.

Därefter berättar vi om fortsatta studier och att vi önskar ha fortsatt kontakt för intervjuer eller deltagare till en workshop. Vi uppmanar folk att skriva upp sig på vår maillista.

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Figure B.2: Interview questions.

C

Use Cases

Below follows our initial use cases, to find our final use cases go to 6.3.6 or look at our PEP-model in the result chapter 7.

C.1 Initial use cases

USE CASES

CASE 1

A pedestrian crosses the street.
The pedestrian enters the platform.
The pedestrian crosses the tracks.
The pedestrian enters the other platform.

CASE 1

A passenger exits the bus.
The pedestrian enters the platform.
The pedestrian crosses the tracks.
The pedestrian enters the other platform.

CASE 2

A bicyclist follows the bus.
The bus stops at a platform.
The bicyclist passes the bus.

CASE 2

A bicyclist follows the bus.
The bus stops at a platform.
The bicyclist passes the bus.

s

Figure C.1: Initial use cases.

D

User scenarios

D.1 Workshop user scenarios

The final user scenarios in full, read more about them in the design process in 6.3.6.

USE CASE
1

LET'S CROSS THE STREET WHILE NO ONE'S LOOKING!

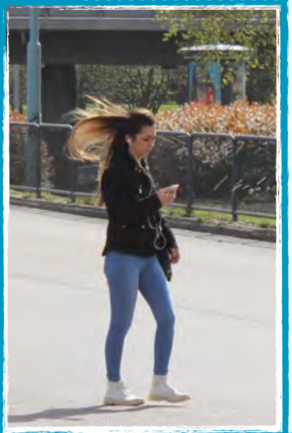
The bus is leaving, the driver isn't looking and the pedestrian is crossing the street.

We've all done it, used our amazing gift of imagination and stepped out in the street. Usually the bus driver monitors us but there's a lot of people in motion around the bus.

How can

- **The bus inform the driver?**
- **The bus get the pedestrians attention?**

USE CASE
2



HOLD UP! THIS FACEBOOK POST IS REALLY FUNNY.

Sometimes we're superbad at priorities.

Failing to multitask is easy. Sometimes we don't even notice that we fail at multitasking, like when two 18 m busses are tooting their horns at us. Maybe it have happened to you but you never noticed it?

How can

- The bus get the pedestrian out of the way?
- A warning be strong enough to get this pedestrians attention?

USE CASE
3

THERE'S NO RUSH WHEN THE BUS ISN'T THERE YET

Maybe it's because you walk in front of its side mirror very slowly

Confusion sets in when you're wondering why the bus is late. You see that everyone else is annoyed as well. The bus driver didn't even say hello. Strange! Side mirrors are very dangerous for tall pedestrians as well.

How can

- The bus encourage pedestrians to walk further away from the platform?
- Pedestrians avoid side mirrors

USE CASE
4

THE BUS IS YOUR FRIEND - A REALLY CLOSE FRIEND.

But it's good to keep your distance,

Confusion sets in when you're wondering why the bus is late. You see that everyone else is annoyed as well. The bus driver didn't even say hello. Strange! Side mirrors are very dangerous for tall pedestrians as well.

How can

- **The bus encourage pedestrians to walk further away from the platform?**
- **Pedestrians avoid side mirrors**

USE CASE
5

YOU'RE ALWAYS SAFE IN A CROWD,

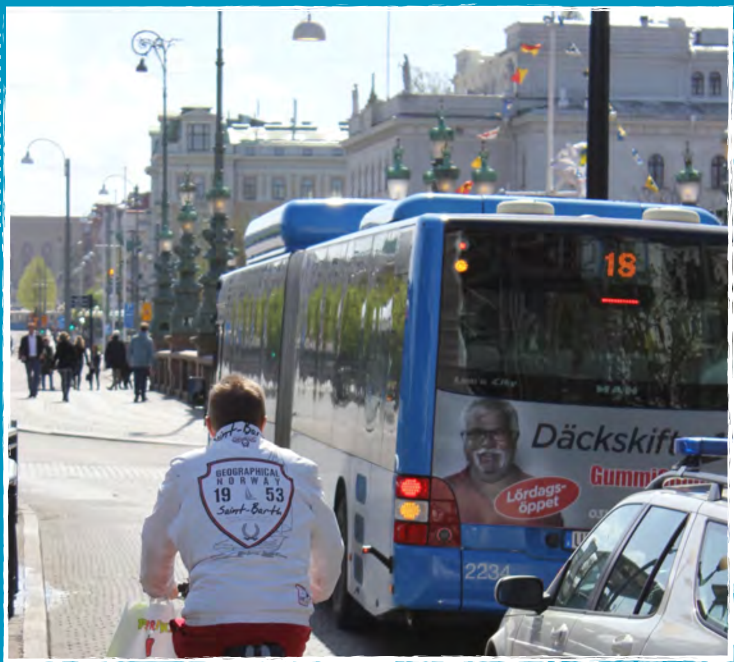
But everyone on the bus arrives late and those are really the crowd. The bus driver gets super tired as well…

Classic occurrence is after a music concerts, events or some special locations in Gothenburg. At some point we waiver our right of passage, trying to be nice. Have you ever hesitated when crossing the road?

How can

- **The bus disperse the crowd when needed?**

USE CASE
6



BIKING IN THE CITY IS NICE.

If you're not squeezed between a bus and a platform fence.

It's hard for city planners to change plans. E. g. adding biking lanes where it wasn't planned. A consequence could be crossing paths, like above. When the bus blinks and leaves the platform biker must be detected.

How can

- **The bus driver better show his/her intention?**
- **The bike know when the bus is pulling out?**

D.2 12 short stories

12 initial scenarios later developed to the 6 user scenarios D.1

12 SCENARIOS

SCENARIO 1

X is rocking his new headphones on the way to school. It's the same old bus that he has used the recent years. X is autopiloting his way to the bus and suddenly notice the approaching bus! X had completely forgot about the opposite lane, i.e. for traffic in the other direction. He thanks his lucky star that the bus driver noticed him and shuffles over the crosswalk slightly embarrassed by his behaviour in traffic.

SCENARIO 2

X is new in town and do not know that you're prohibited from walking outside the Nils Ericsson Terminal. X tries to reach nordstan on foot when a bus is hastily reversing towards him/her. Since X is in the blind spot he/she is helpless and can't escape the reversing bus.

SCENARIO 3

X exits through the front dor of the bus, the door closes when X set foot on the platform. X wants to cross the street but don't know if the bus will leave the stop or not. Since the bus isn't moving, X assumes that it's okay to pass in front of the bus. Just as X hesitates another passenger sets foot on the crosswalk, in the same moment the buss jumps forward but immediately have to slam the breaks. Now everyone cross the street in front of the bus.

SCENARIO 4

X is in a hurry and needs to make the connection at Kungsportsplatsen. As X run in front of the bus he/she missed the bike in the bike lane which was overshadowed by the bus X was on.

SCENARIO 5

X is riding the bike towards Kungsportsplatsen. X is catching up to the bus in the bus stop. As X is alongside with the bus the bus starts to turn into the lane and pushes X towards the fence.

SCENARIO 6

X is riding the bike and is closing in to the intersection at Berzeliigatan. The bike lane crosses the warning triangles printed on the asphalt. A bus is coming from Götaplatsen but the driver misjudges the de-acceleration as there's many passengers in the crowded bus and the significance of the slope. As the front of the bus points out over the bike lane, X does a split-second call and decides not to go in front of the bus. Instead X plays it safe and turns left and crashes into the bus.

SCENARIO 7

X must run in order to catch his/her bus. Sprinting across the road before reaching the bus required all the attention in order to not be hit by the cars. However the bus who X tried to catch run him/her over as X is right in front of the bus.

Figure D.1: User scenarios formed from observation and interviews.

SCENARIO 8 & SCENARIO 9

When X leave the shopping mall she/he notice that her/his bus is passing by and stopping at the platform 100 meters away. X starts to run but when the light on the doors goes out she/he knows that it is too late, the doors are locked and that bus is going to leave the platform.

SCENARIO 10

X did not have time to look up the departure for the bus, but is aware that the bus only have 2 departures an hour. When X notice that the bus is standing at the platform X starts to run to make it onto the bus not having to wait for 30 min until next arrival. X enter the bus and finds an empty seat. However the bus driver now leaves the bus for his break and X have to wait 7 min for departure.

SCENARIO 11

X is ready for a night at town, when he approaches, he sees that the bus just drove in and stopped at the stop. Since it took time to get prepared , he/she does not run and get sweaty on the way to the event. Which result in X missing the bus.

SCENARIO 12

x has been in the grocery store and come carrying two large shopping bags. With the bus in sight, he goes with certain strife against the bus. The bus driver looking in the back mirrors to see that everyone has had time to board, closes the doors and are just about to leave when he notice X just in front of the bus . The driver opens the doors and lets board X , closes the doors for X and start driving.

Figure D.2: User scenarios formed from observation and interviews.

E

Light concepts

E.1 Eco

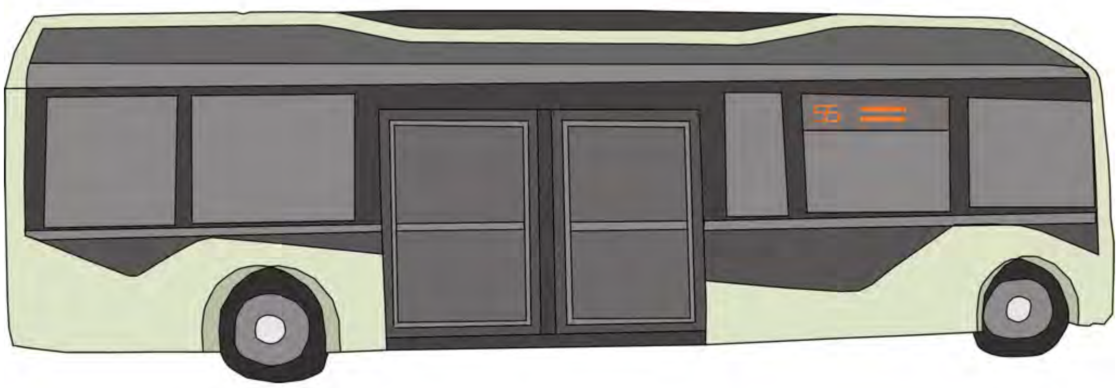


Figure E.1: Light sketch from the Eco concept, state 1

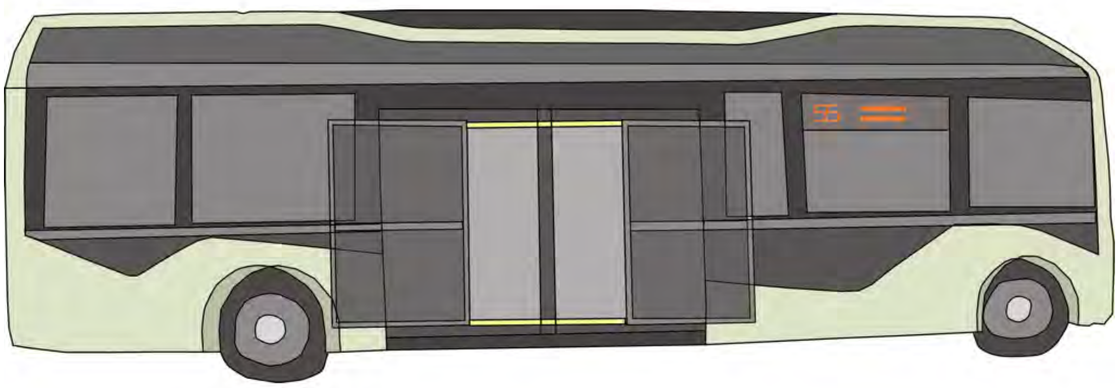


Figure E.2: Light sketch from the Eco concept, state 2

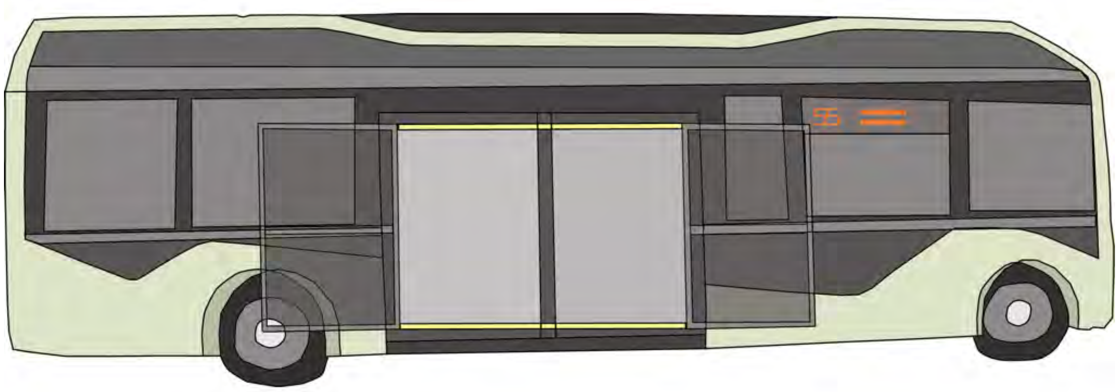


Figure E.3: Light sketch from the Eco concept, state 3

E.2 Care

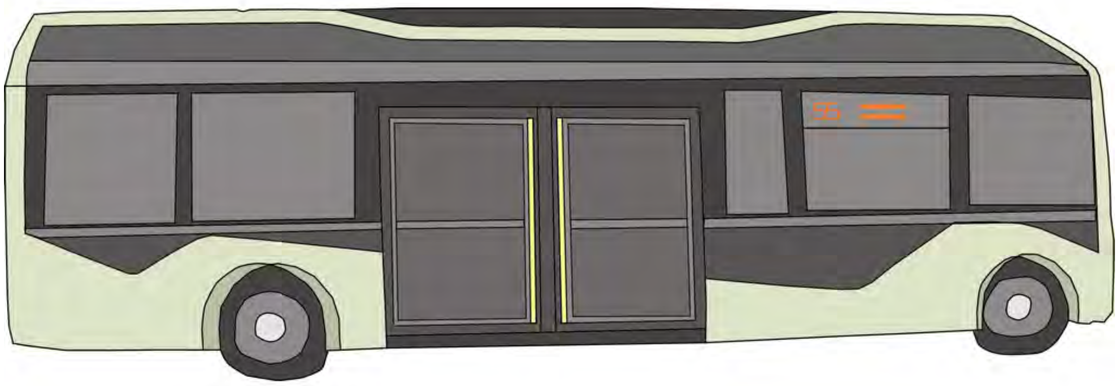


Figure E.4: Light sketch from the Care concept, state 1

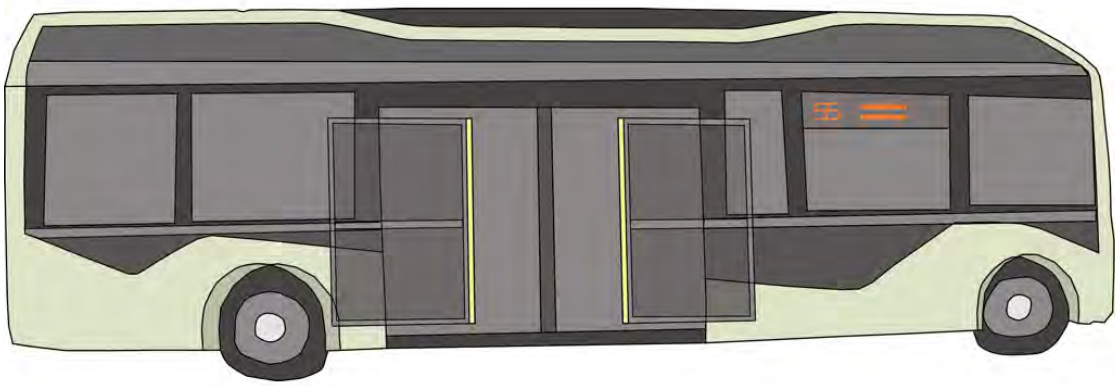


Figure E.5: Light sketch from the Care concept, state 2

Figure E.6: Light sketch from the Care concept, state 3

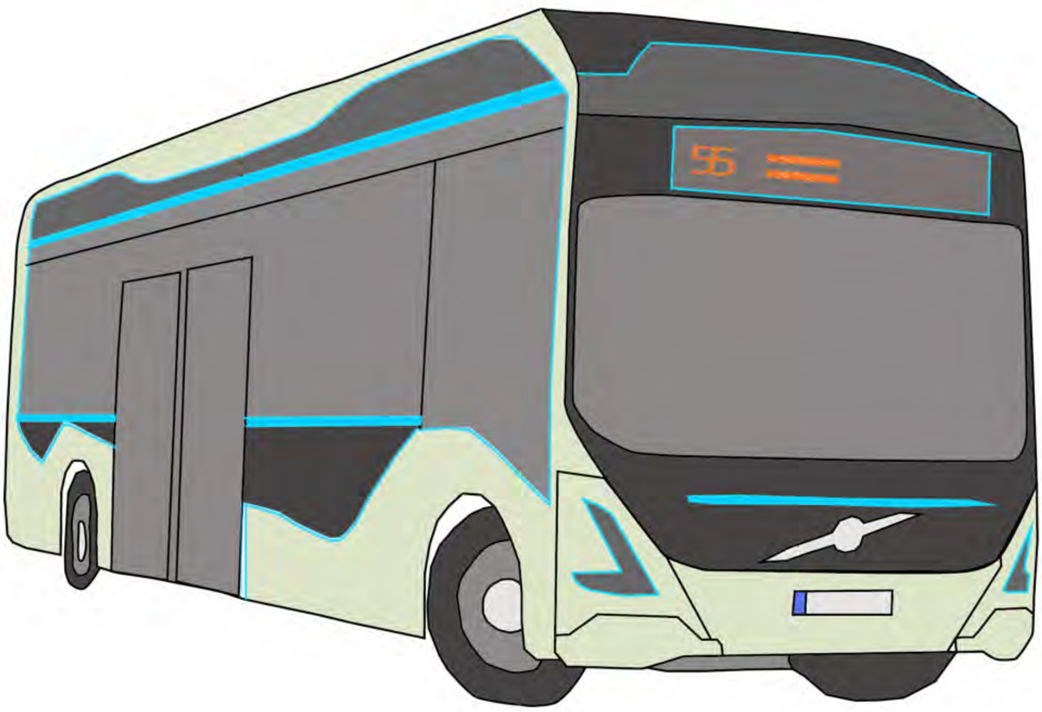


Figure E.7: Bright led lights, illustrate the care concepts vision of saving every life

Figure E.8: Care concept, highlighting the side mirror, state 1

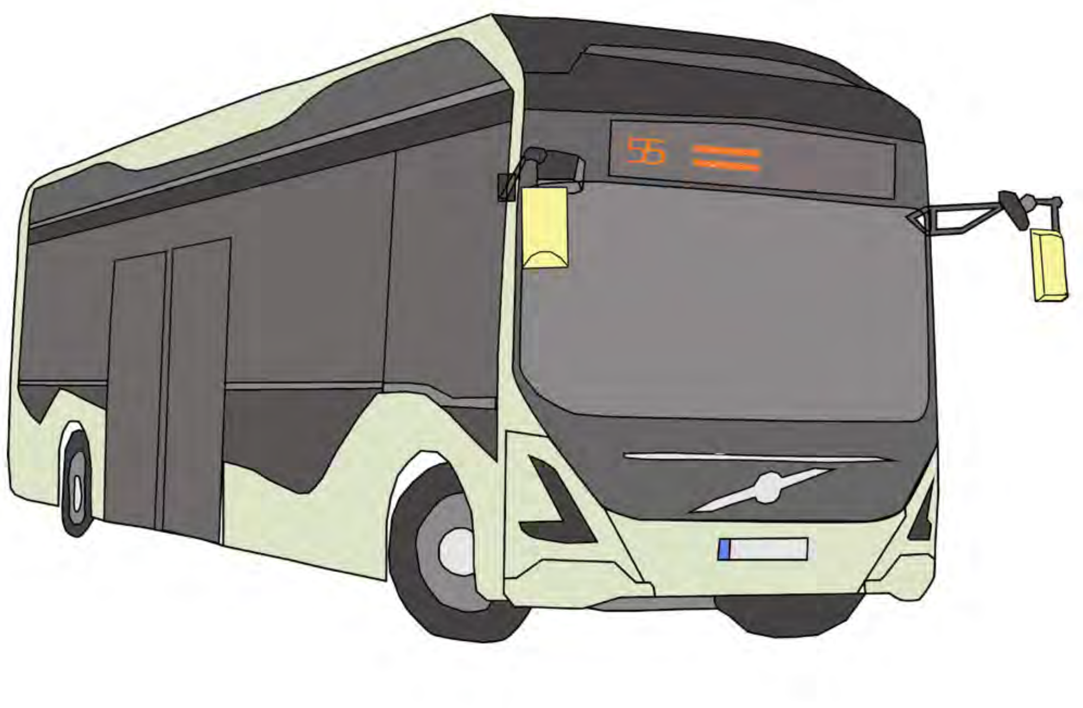


Figure E.9: Care concept, highlighting the side mirror, state 2

Figure E.10: Care concept, highlighting the side mirror, state 3

E.3 Express

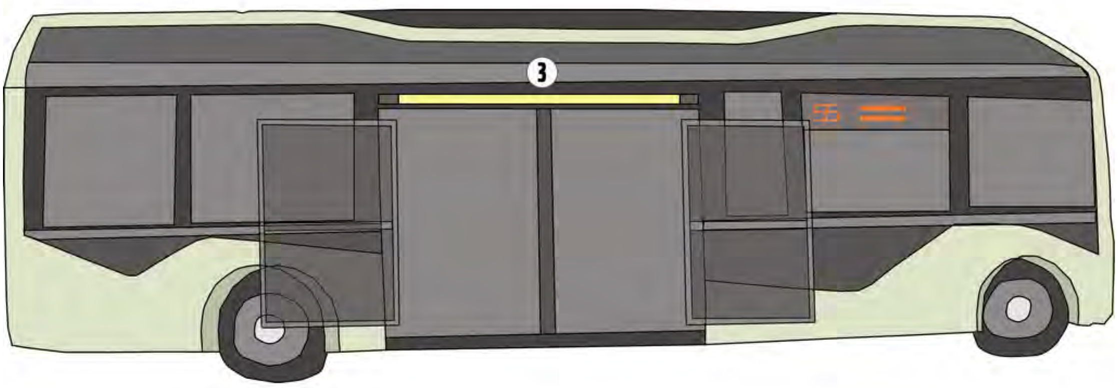


Figure E.11: Light sketch of closing door from the Express concept, state 1

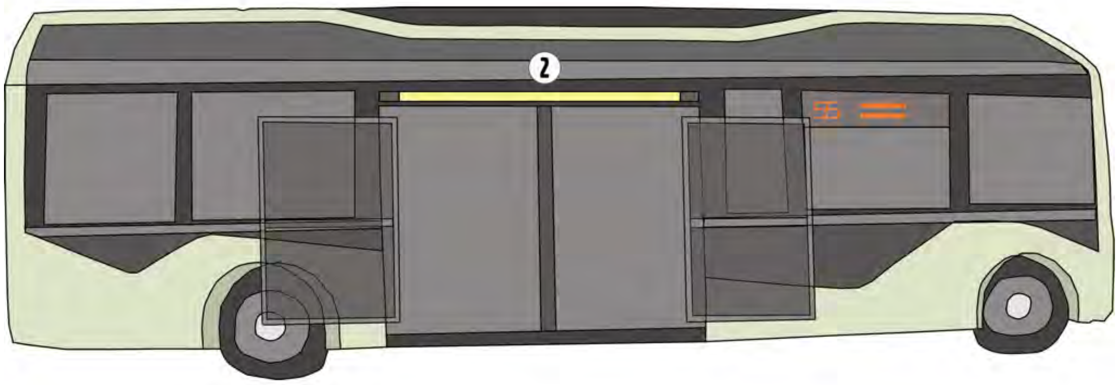


Figure E.12: Light sketch of closing door from the Express concept, state 2

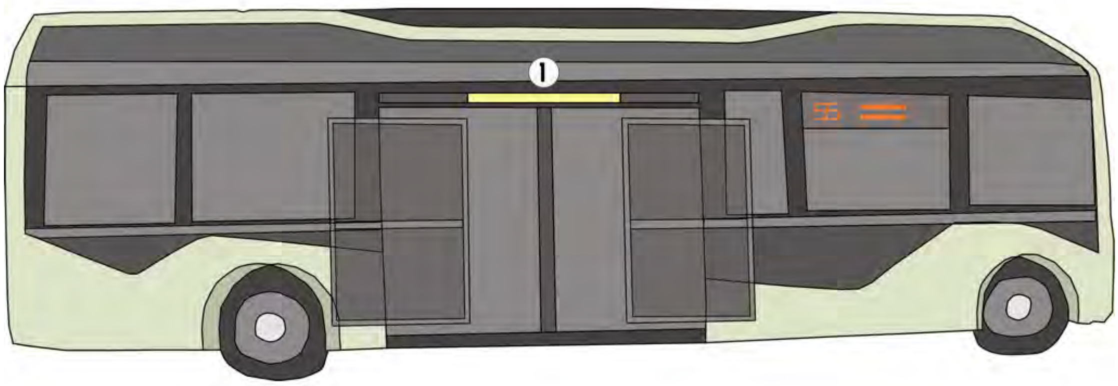


Figure E.13: Light sketch of closing door from the Express concept, state 3

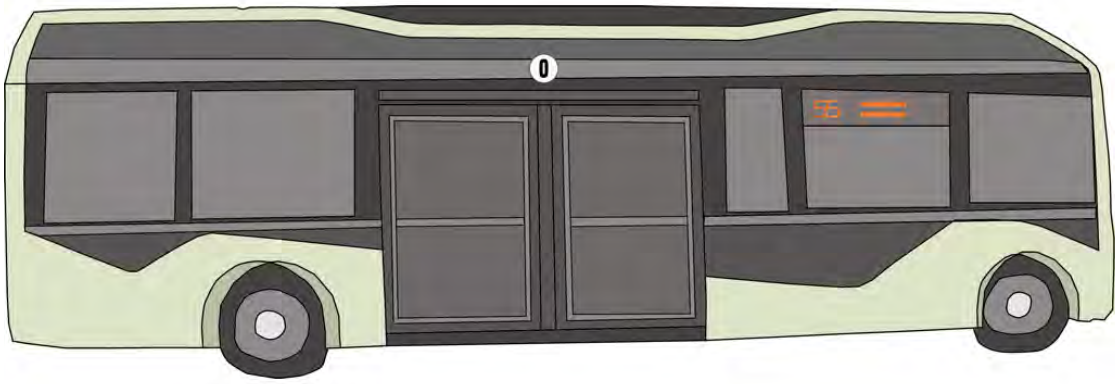


Figure E.14: Light sketch of closing door from the Express concept, state 4

Figure E.15: By using universal language on the side mirror the driver can express intentions

Figure E.16: By using universal language on the side mirror the driver can express intentions

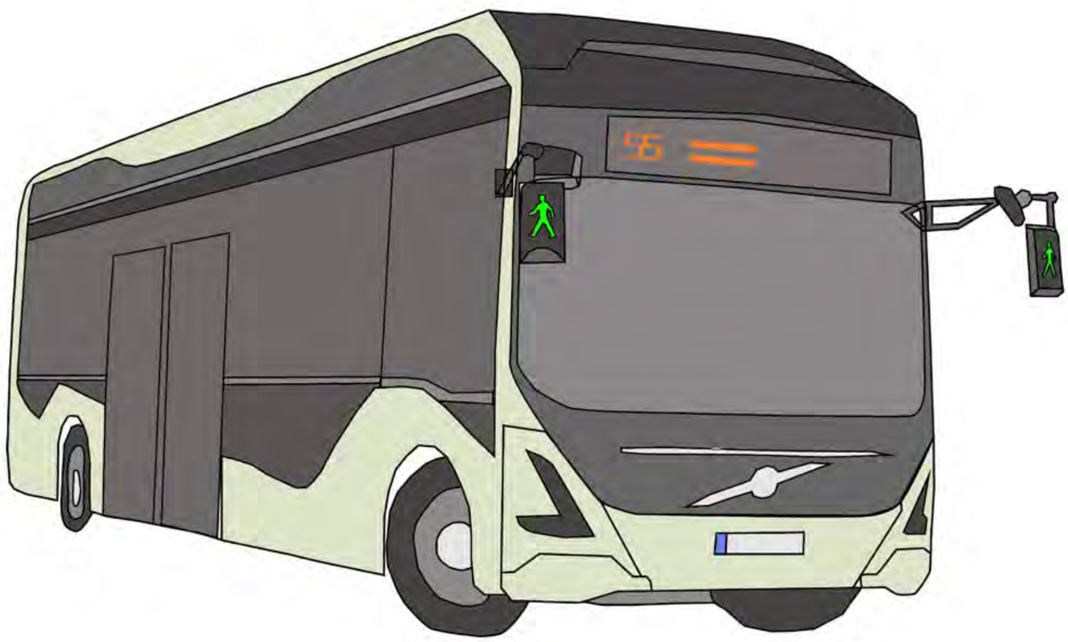


Figure E.17: By using universal language on the side mirror the driver can express intentions

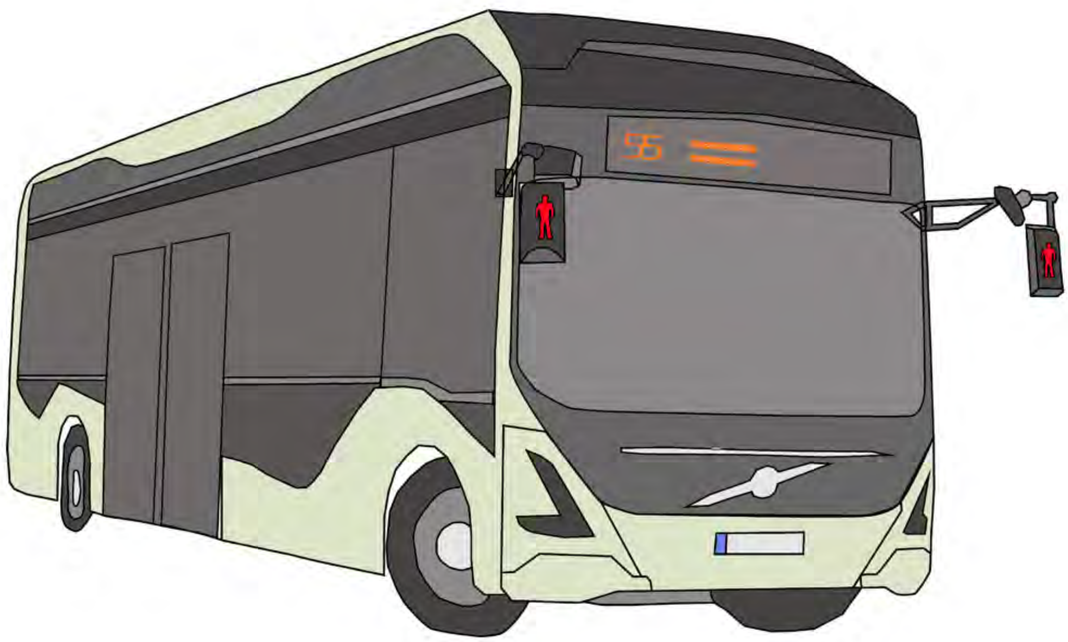


Figure E.18: By using universal language on the side mirror the driver can express intentions

Figure E.19: Big front displays for attention, using different hues to convey current state.

Figure E.20: Big front displays for attention, using different hues to convey current state.

Figure E.21: Big front displays for attention, using different hues to convey current state.

Figure E.22: Big front displays for attention, using different hues to convey current state.

Figure E.23: Big front displays for attention, using different hues to convey current state.