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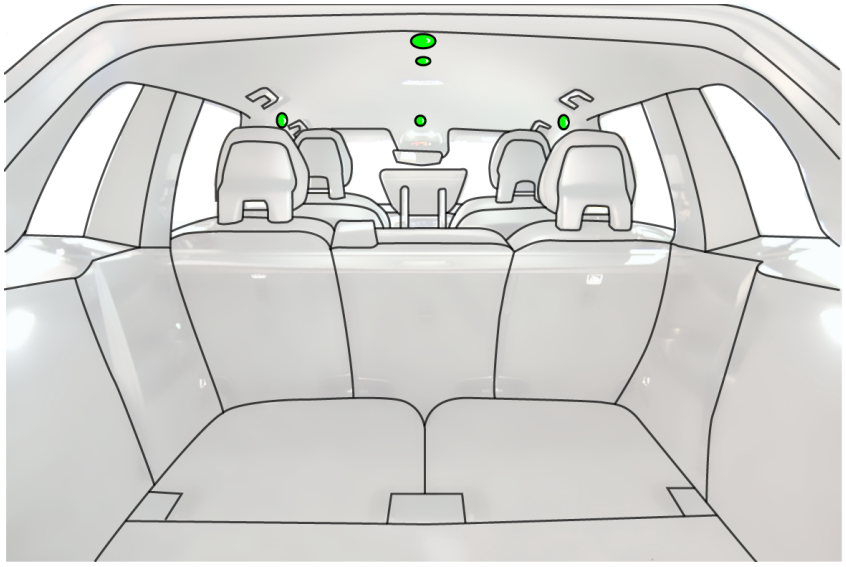

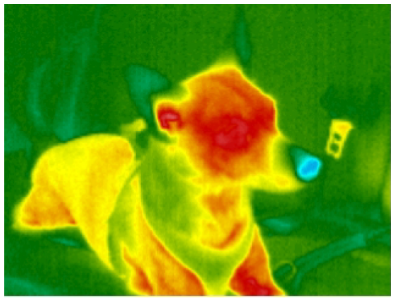

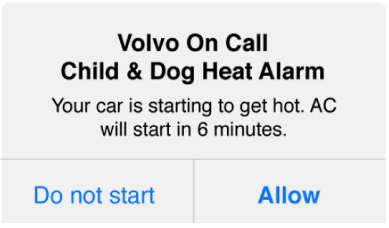

Preventing hyperthermia among children and dogs left in cars

Development of a system to be implemented in future cars

Master's thesis in Product Development

JOSEPHINE ERIKSSON & MELTEM TEMUR

Department of Product and Production Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2016

Master's thesis 2016

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Cover: Infrared camera placement description, along with infrared camera image of a dog and a notification used in the developed system.

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Abstract

Every year several children and dogs around the world are suffering from hyperthermia and heat illness after being left or forgotten inside of cars that get hot. In this thesis the possibility of implementing a system in cars in the future that eliminates serious hyperthermia cases among children and dogs that are left in cars that get hot is investigated.

The project research has shown that people are aware of the problem and its consequences but do not understand how fast cars can heat up, and how insufficient solutions such as lowering the windows of the car are. There is a need of a system solving the problem that is integrated in the car, and does not rely on user behaviour.

A conceptual system that solves this problem has been developed. The development process consisted of several phases, with each phase being iterated before moving on to the next. As the development moved from phase to phase the level of detail increased. With the results from each design phase new needs and requirements were set for the development during the next phase. To gather information and data related to the problem literature studies, questionnaires and interviews have been used. The development work was carried out using engineering methods such as the Pugh and Kesselring matrices and brainstorming techniques.

The developed conceptual system resulted in an integrated solution “HeatSafe”, consisting of infrared cameras to detect any child and/or dog left in the car, utilising the AC system to cool the interior of the vehicle, the built in thermometer in the car to trigger the cameras, an mobile application to deliver information to the user and the car software to run the system.

To conclude, the system is feasible for implementation in the future, and a suggestion is to start implementing it in hybrid vehicles where running the AC does not cause emissions. In the current situation the infrared cameras are not economically feasible, but with future development and full scale quantities the concept is possible to integrate in future vehicles.

Keywords: hyperthermia, heat, dog, child, car, infrared, camera, concept, cooling, safety.

Acknowledgements

First of all we would like to thank our examiner and supervisor Lars-Ola Bligård at Product and Production Development, Chalmers University of Technology. Whenever we ran into trouble he answered our numerous e-mails with such a hurry that we did not have to spend time on worrying for long. Also we are grateful towards Stefan Wedin, supervisor at Escenda Engineering, for allowing us to do this project at Escenda and believing in it, and making sure we got in touch with relevant contacts during the project. We would also like to thank him for allowing us to borrow his car, and allowing us to put dogs in it for research purposes.

We would also like to thank all experts at Chalmers University of Technology for providing advice on technical details during the project. Associate Professor Magnus Karlsteen at the Department of Physics who provided advice on infrared technology and borrowed us cameras for use during tests. Industrial doctoral student Filip Nielsen at the Building Services Engineering department for providing knowledge and advice on climate and air conditioning systems not found elsewhere in the literature. Professor Ola Carlson at the Energy and Environment department for giving advice on solar cell panels. In addition, senior lecturer and Deputy Head Ingvar Albinsson at the Department of Physics at University of Gothenburg for borrowing us the Flir camera.

We would also like to thank all the participants in interviews and tests during the project, both the dog owners and parents, but also the veterinarians and paediatrician. Also a thanks to the dog owners who came to the office to allow their dogs to be photographed with the infrared camera in the car. A special thanks to the Facebook group Bar & café (GWU), thank you for supporting this project with answers to the questionnaires, persons who participated in interviews, borrowed their dogs for photographing and providing advice on dog cages.

Finally, we would like to express our gratitude towards our friends and families for supporting us not only during this project but throughout our years at Chalmers. Despite our constant unwarranted worries we managed to finish the project without major struggles. It went smoothly. Thank you.

Josephine Eriksson and Meltem Temur, Gothenburg, May 2016

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1
Introduction

This report describes a master's thesis of 30 credits. The thesis aims to solve the problem of children and dogs being left in cars that get hot with the development of a new solution in collaboration with *Escenda Engineering AB* consultancy firm. The project is carried out by two students studying the master programme *Product Development* at *Chalmers University of Technology*.

1.1 Background

Every year media reports about dogs suffering from hyperthermia after being left in cars that get hot. Swedish animal insurance company *Agria* has recorded statistics showing that seven dogs each year die due to hyperthermia in Sweden. Cars left outside may reach an internal temperature of 85°C, when the temperature outside is 20°C (Gunnarsson, 2015).

Dogs do not have the same ability as humans to lower their body temperature by sweating; they instead get rid of heat by panting, which is a less efficient cooling system compared to sweating. If left in a car that gets too hot this means that the dog will not be able to keep its body temperature in a safe range or cool down when the temperature increases, and after some time the result is hyperthermia (Foster and Smith, 2015). Hyperthermia might lead to internal damages to the brain, heart, kidney, intestines and/or liver that are potentially lethal (Möller, 2012).

It is not only dogs that suffer from heat illness after being left in hot cars. The American organisation *Kids and Cars* reports that on average 39 children die in the United States each year due to vehicular heatstroke, based on statistics between the years 1991-2013 (Kids and Cars, 2015).

Today many seem to try to solve the problems occurring when their dog is purposely left in a hot car by lowering the windows in the car, but generally people do not seem to use any products designed to solve the problem. Together with the consultancy firm *Escenda Engineering AB*, that have the automotive industry as a origin and core business (Escenda AB, 2016a), this thesis will investigate the needs and problems related to children and dogs that are left in cars during hot days, and develop a conceptual system to prevent hyperthermia among children and dogs left in hot cars. The solution is developed for use in the car *Volvo XC90* produced by the Swedish car manufacturer *Volvo Car Sverige AB*, also conforming to the *Escenda*

mission; "*Escenda creates value by offering product development services to clients operating on a global market. We are driven by passion, innovative thinking and a desire to make a difference. With our products and services, we want to improve and simplify life for people and companies all over the world*" (Escenda AB, 2016b). Except for conforming to *Escenda*'s mission the project also coincides well with *Volvo*'s vision. "*That no one will be seriously injured or killed in a new Volvo by 2020*" (Volvo Cars, 2016a).

1.2 Purpose

The purpose with this master's thesis is to investigate the possibility of implementing a system in cars in the future that eliminates serious hyperthermia cases among children and dogs that are left in cars that get hot.

1.3 Goal

- Investigate the problem in order to create a problem description including needs, requirements and results from the study for future use.
- Delivering a representation of a feasible concept that solves the problem.

1.4 Structure of report

In this report the chapters are divided into the different design phases; pre-study, subsystem concept design, full system concept design, detailed design and final concept. After this follows a general discussion and a conclusion. The results and analysis of each phase are integrated in each chapter, except from parts of the pre-study that are described in the theory chapter. In the chapter called methods and implementation each section describes a method used, followed by the way it was implemented for the project.

- **Introduction**, see chapter 1 on page 1.
- **Theory**, where the theory found in the literature study and medical interviews is presented, see chapter 2 on page 5.
- **Methods**, where the used methods and the implementations of the methods are presented, see chapter 3 on page 23.
- **Pre-study**, where the results and analysis from the benchmark, user interviews and questionnaire are presented. In addition the general needs and user needs of the system are described, see chapter 4 on page 39.
- **Subsystem concept design**, including results and analysis, in addition the full system requirements are described, see chapter 5 on page 63.
- **Full system concept design**, including results and analysis, in addition the element requirements are described, see chapter 6 on page 69.
- **Detailed design**, including results and analysis, in addition the detailed element requirements are described, see chapter 7 on page 85.

- **Final concept**, where the final concept is described and evaluated, see chapter 8 on page 107.
- **Discussion**, see chapter 9 on page 113.
- **Conclusion**, see chapter 10 on page 121.

2
Theory

As a part of the pre-study theory related to the topic of hyperthermia among children and dogs left in cars was researched. In this chapter the researched and used theory is presented. Mostly the theory is derived from the conducted literature study, but to complete the results from the theory medical interviews with veterinarians and a paediatrician are also used as reference material. In the end of the chapter the *Volvo XC90* with its features is introduced, and the heat ventilation air conditioning system of cars is described.

2.1 Hyperthermia and heat illness

Hyperthermia is defined as a body condition when the body gets overwhelmed due to increase of temperature, leading to a loss of control of the body temperature range (Grundstein et al., 2015).

Heat illness can be divided up in three different phases but is seen as a continuum. The first phase is defined as heat stress, the second as heat exhaustion and the third as heatstroke. The heat stress is the least dangerous phase while the third, heatstroke is the worst (Kuska, 2012). Heat exhaustion can also be defined as reversible heat illness while heatstroke causes tissue damage that is irreversible (Hoffman, 2001).

Heatstroke is an illness that occurs more often among dogs than humans. Among humans heat exhaustion is more common. Moreover heatstroke is dangerous for both humans and dogs since it is very rapid and can lead to fatality (Stanley, 1980).

2.1.1 Heat stress

The first phase of heat illness is defined as heat stress. Heat stress is the form of heat illness that is regarded as least dangerous among the continuum. Because of high temperatures in the environment the body reacts with physical discomfort and also physiologic strain leading to heat stress (Kuska, 2012).

2.1.2 Heat exhaustion

The second phase of heat illness is heat exhaustion (Kuska, 2012). Heat exhaustion is known to occur when a human or a dog gets exposed to high temperatures during

a prolonged time. In an environment with high temperature the peripheral vessels (such as arms and legs) usually dilate making it easier to dissipate heat. However if the vascular system (circulatory system) is not capable of handling these changes, heat exhaustion occurs (Stanley, 1980).

2.1.3 Heatstroke

Heatstroke is the third and the most severe phase of the heat illness continuum and is characterised differently for dogs and for humans. For humans a core body temperature above 40°C is seen as dangerous and for dogs this temperature is slightly higher, 41°C. Except the increase of the body temperature, dysfunction in the central nervous system is also present as a characteristic of the illness (Bruchim et al., 2006). The human body develops difficulties with sweating and cooling down its temperature increasing the risk of damage in the brain and organs (Kuska, 2012).

2.2 Heat effect in cars

When a car is parked in the sun the rays of the sun enter the car through the windows and strikes the interior surfaces. If the windows and doors are closed the heat does not exit the car, and the temperature rises. This can happen even if the temperature outside is rather cold, as long as the weather is sunny (Kuska, 2012).

A study of a car placed in the sun by McLaren, Null, and Quinn, 2005, has shown that the temperature in a car increases rapidly, independent of outside temperature 80% of the increase happens during the first half hour. The maximum internal temperature occurred after approximately 60 minutes of exposure. The mean value of increase was 3,2°F (1,78°C) every fifth minute. With an outside temperature of 96°F (35,6°C) the inside temperature rose an additionally 40°F, equalling in total a temperature of 57,8°C within an hour. Also, lowering the windows of the car did not make any difference to the final temperature or the rate of heat rise when lowered 3,8 centimetres (McLaren, Null, and Quinn, 2005).

Another study found that the temperature inside a car parked in New Zeeland rose 0,9°C per minute during the first 20 minutes, with a rise of 1,05°C per minute measured at most (Gregory and Constantine, 1996).

2.3 Dissipation of heat

As stated by Brashear, 2015 and Hoffman, 2001, dogs and children dissipate heat from the body surface to the surrounding with four mechanisms:

- Conduction
- Convection
- Radiation
- Evaporation

2.3.1 Dissipation in children

Children acquire heat when the environmental temperature is higher than the body temperature. When the body needs cooling the heat is first transferred from the core of the body towards the skin surface by the blood circulating and by conduction through the layers of tissue and fat. After this the heat is transferred from the body surface to the environment through the four mechanism listed above (Hoffman, 2001).

According to Hoffman, 2001, radiation occurs when infrared waves are transferred from the body and usually 60% of the body heat is lost through this. Evaporation stands for about 22-25% of the heat loss, where liquids such as water or sweat on the skin are turned into gas. During this the remaining molecules in the liquid loose energy, resulting in cooling. About 3% of the cooling is created with conduction. Conduction occurs when objects in direct contact transfer heat. Convection stands for about 12-15% of the cooling and occurs when the skin is cooled by air. The air next to the skin is heated through conduction and radiation and transported away and exchanged to colder air by currents. If air movement increases the convection can increase to 60% of the total heat loss (Hoffman, 2001).

In the cases where the environment is hotter than the skin surface heat is transmitted to the skin with conduction and radiation, instead of away from it. During these circumstances evaporation is the only way of cooling the body. However, at a humidity of 75% the evaporation decreases, and at 90-95% humidity the evaporation is almost zero (Hoffman, 2001).

As described by Hoffman, 2001, children are less tolerant to extreme temperatures and humidity compared to adults, since children have a larger production of endogenous heat per kilogramme of body weight. In addition the surface area in relation to the body mass is larger among children, increasing the efficiency of the heat transfer between their bodies and the surroundings. Children also have less ability to sweat compared to adults, and the evaporative heat loss is not as efficient as among adults. Small children are not able to tend to themselves, and are depending on adults for changing clothes (Hoffman, 2001).

2.3.2 Dissipation in dogs

Usually when the dogs use the four mechanisms mentioned above the dog is able to stay comfortable. Conduction usually occurs when the dog lays down on a surface that is cool. Convection is the case when the dog is cooled by air that blows on the skin, radiation when the dog releases heat from their body to the atmosphere and evaporation which in the case of the dog is not due to sweat but to panting (Brashear, 2015). Panting is the main way for the dog to regulate the temperature, while sweating is rather unimportant (Stanley, 1980).

2.4 Symptoms of heat illness

Heat illness related to hyperthermia is divided into different degrees of severity, heat stress, heat exhaustion and heatstroke as mentioned in section 2.1. The disease progression is somewhat different between dogs and children and is described in the sections below.

2.4.1 Symptoms among dogs

According to interviews with veterinarians in the Gothenburg area, see table 3.1 in section 3.2.2, the first visual sign of hyperthermia is that the dog pants vigorously. This panting is the way the dog regulates the temperature, but it is not nearly as effective as the human sweating ability. The dog may also have cramps in the later stages of hyperthermia. At first the dog pants more and more, after a while when the heat exhaustion progresses into a heatstroke it might loose consciousness, have cramps and later it will die. You can also notice wheezing sounds from the lunges due to *pulmonary edema* (water in the lunge). Other symptoms that are visual include bloody diarrhea. The dog can also have regular diarrhea due to the stress of being locked in a hot car. But, one of the veterinarians pointed out, the most clear symptom is the panting. For a flowchart of the visual symptoms, see figure 2.1. The symptoms marked in bold are symptoms found in the literature, see the following paragraphs.

The symptoms described by the interviewed veterinarians are further described in the studied literature. Initially dogs that suffer from heat exhaustion will be restless, the dog will pant heavily, and may hyperventilate. The amount of saliva increases, and eventually the mucous membranes will get dry (Animal Medical Center of Southern California, 2015). The late signs includes that the mucous membranes get pale and the extremities get warm and the dog may tremble. The dog may have increased amounts of saliva, vomit and is weak (Stanley, 1980). When suffering from heatstroke the main symptoms are very high body temperatures and sudden collapses. Early signs that the dog is suffering from heatstroke also include dehydration, depression, vomiting, diarrhea, bounding pulses, *tachypnea* (rapid breathing) and *tachycardia* (high pulse) (Shell, 2007).

Further on the dog may suffer from *hematemesis* (vomiting blood), bloody diarrhea, seizures, *cerebellar signs*, collapse, *oliguria* (small amounts of urine), severe respiratory distress, *cyanosis* (blue color on the skin) and *petechial hemmorhages* (bleedings from small spots of the skin) (Shell, 2007).

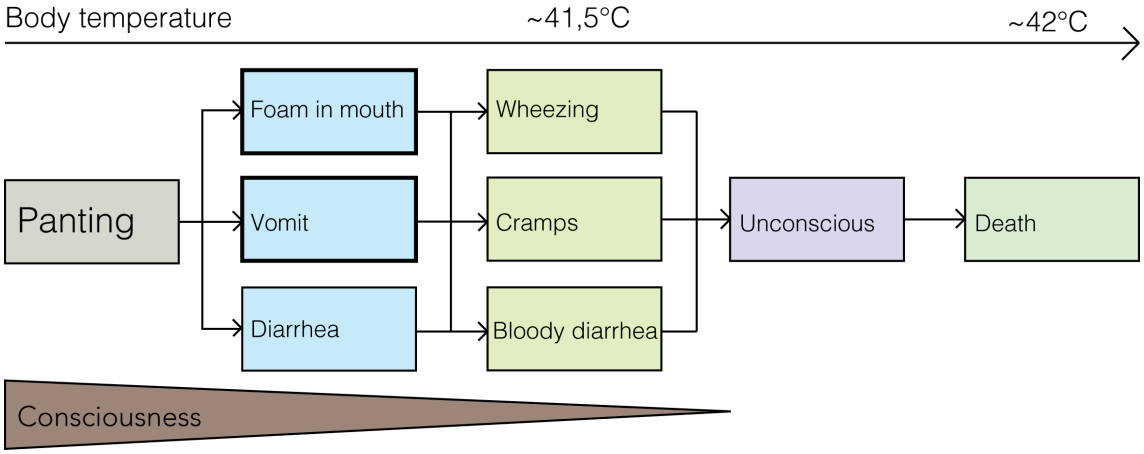


Figure 2.1: Flowchart of visual symptoms among dogs

Except from visual symptoms the veterinarians, see table 3.1 in section 3.2.2, also described non-visual symptoms. When suffering from hyperthermia the dog has a high body temperature and when the body temperature reaches above 41,5°C there is a risk of large damages on the body, and above 42°C the dog is almost dead. Inside of the dog the mucous membranes of the dog are dry and since the dog has panted a lot it does not gain enough oxygen. This results in dead space, when the air only passes through the space in the dog's throat between the outer air and the lungs, not reaching the actual lungs. Due to hyperthermia there is toxic changes in the lunges, brain and blood.

The dog can suffer from serious damages due to heatstroke; *myocardial damage* (heart damage), brain damage or *pulmonary edema* (water in the lunge). The collapse of the organs will follow the initial visual signs of panting, and according to the interviewed veterinarians any organ may suffer. It is impossible to know which in beforehand. You may also have a *hypovolemic shock* due to the disturbances in fluid balance. For a flowchart of the non-visual symptoms, see figure 2.2. The symptoms marked in bold are symptoms found in the literature, see the following paragraphs.

In the literature this hypovolemic shock is also described. According to Brashear, 2015 his occurs when the body brings as much blood to the surface as possible in an attempt to cool down. The panting itself can dehydrate the dog. A hypovolemic shock happens when the heart is unable to pump enough blood to the body (Heller, 2014). Patients suffering from heatstroke can suffer from cell rupture, and at higher body temperatures of 49-50°C cellular necrosis occur, resulting in edema (Brashear, 2015). Further on, according to Stanley, 1980, as the heatstroke continues there is a decrease in cerebral functions because of *cerebral* (brain) edema. As this continues the cerebral edema results in a coma, and the dog is not able to pant anymore. At this stage the rate of respiratory slows down and the dog may die (Stanley, 1980).

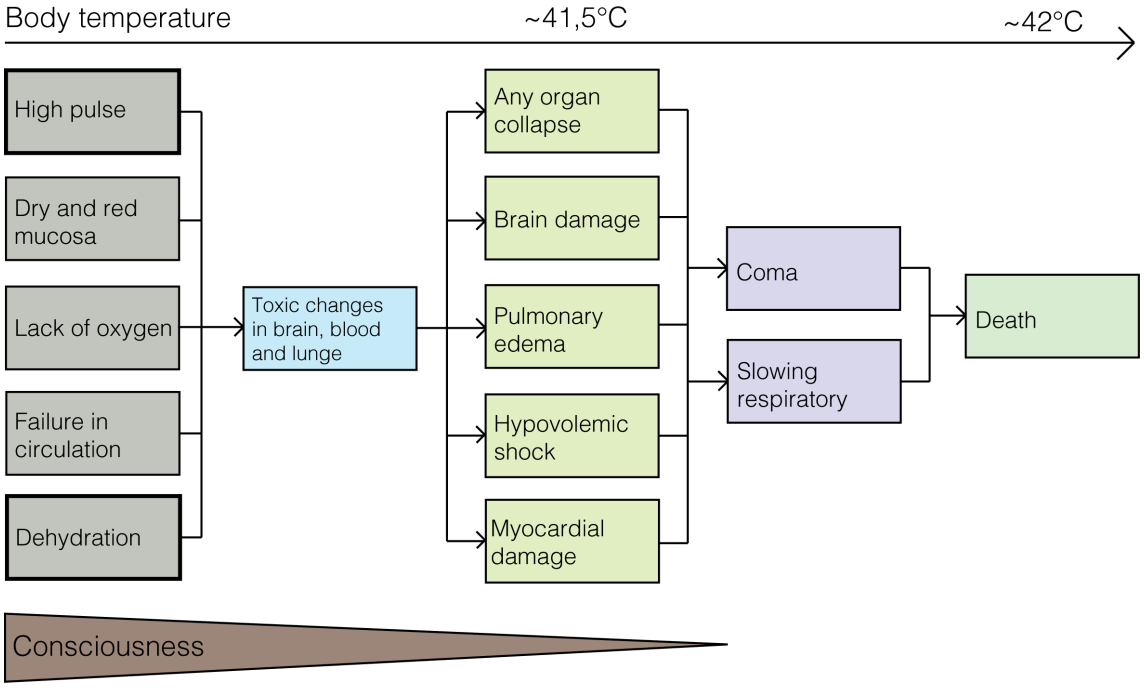


Figure 2.2: Flowchart of non-visual symptoms among dogs

2.4.2 Symptoms among children

According to the interviewed paediatrician in the Gothenburg area, see table 3.1, children suffering from heat exhaustion at first become tired and have trouble eating. Small children in general have trouble regulating their body temperature, and also do not tell their caregivers when they are feeling thirsty. When suffering from heat the children get a high body temperature, get dehydrated and finally unconscious. For a flowchart of the visual and non-visual symptoms, see figure 2.3 and 2.4 below. The symptoms marked in bold are additional symptoms found in the literature, see the following paragraphs.

In addition to the description by the paediatrician, the literature describes the symptoms. The mildest form of heat illness, the heat stress, includes only physiological strains on the body and physical discomfort due to a hot environment (Kuska, 2012).

When the temperature increases heat exhaustion occurs, with dehydration following (Kuska, 2012). During heat exhaustion the child will feel thirsty, dizzy, suffer from headache and general weakness (Chan and Mamat, 2015). The child may also suffer from anxiety, faint and have an increased thirst (Kuska, 2012).

When the heat exhaustion continues the child will suffer from heatstroke (Chan and Mamat, 2015). The child will have a rapidly increasing body temperature, and the body can not cool down. The brain and other organs may become damaged (Kuska, 2012). Heatstroke is caused by thermoregulatory failure, and is noticed by the skin being hot and dry, the child may be mentally affected with delirium, convulsion or coma (Ferrara et al., 2013). The condition includes a multisystem

failure, where the organs collapse. Also, signs such as *tachypnea* (rapid breathing) and *tachycardia* (high pulse) can occur. The patient may end up in a coma, or have seizures and a collapse of the circulatory system is common. The child may also suffer from bleeding from interavenous sites (Chan and Mamat, 2015). As the temperature rises the blood flows towards the extermites of the body, and as fluid and electrolytes are lost there is a large burden on the heart, ultimately resulting in death (Kuska, 2012).

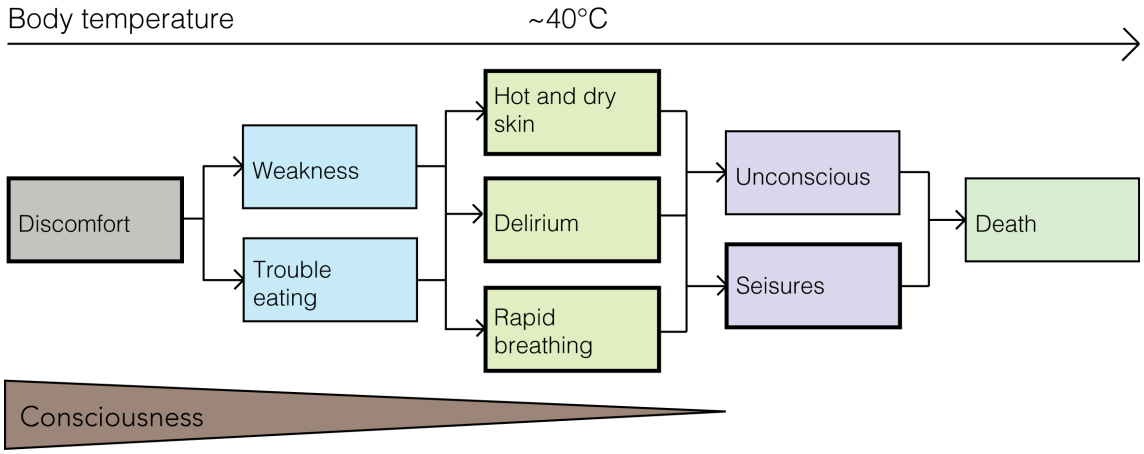


Figure 2.3: Flowchart of visual symptoms among children

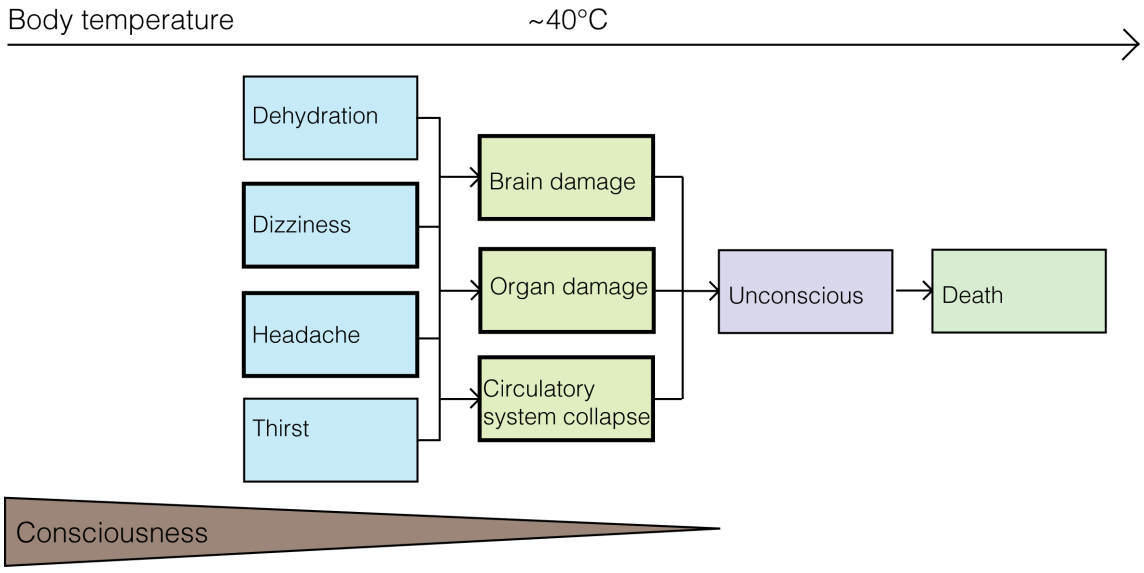


Figure 2.4: Flowchart of non-visual symptoms among children

2.5 Treatment of heat illness

In the following sections the treatment of heat exhaustion and heatstroke are described. As can be noted in the sections the treatment is rather similar, and includes rapid cooling of the patient, and treatments of organs that may fail due to the heatstroke.

2.5.1 Treatment of dogs

According to interviews with veterinarians in the Gothenburg area, see table 3.1 in section 3.2.2, some of the animals are already dead upon arrival to the clinics. Some are only suffering from heat exhaustion and are cooled by a shower. The ones that are suffering from heatstroke however usually have additional injuries on the internal organs, entering a state of shock where the internal organs may collapse. If that is the case intensive care and stabilising the blood pressure and circulation is important. At the clinic you also give intravenous (IV), make sure that the dog can breathe, and give oxygen. In some cases you have to give sedatives due to high levels of stress in the dog. Time is critical and if you wait too long for the police to arrive before breaking a window this can make the difference between life and death. The impression among the veterinarians interviewed were that either you arrive to the clinic in time and the dog will become fully restored, or you are too late and the dog will die. The cases in between do exist but are not common. You have to act correctly in order to ensure the survival of the dog.

The treatment is also described in the literature. Heat exhaustion among dogs are treated by moving the dog to a cool environment, administering electrolytes and IV fluids. Usually the dog's condition is rapidly improved (Stanley, 1980). It is important to start treating heatstroke early and aggressive, managing both the signs that are heat-related and the other complications. Treatments include cooling the dog, supporting the cardiac, reverse the shock, treating seizures, correcting the metabolic imbalance and alleviation of respiratory distress (Reniker and Mann, 2012). When a dog suffers from heat illness the first step is to cool the dog. It is important to use room temperature or warm water, never cold (Brashear, 2015). The cooling needs to start before the dog is transported to the veterinary, and if iced water is used the dog may struggle or shiver, have decreasing heat dissipation and hypothermia. It is also a problem since it may be harder to evaluate the patient if it has been cooled with iced water (Reniker and Mann, 2012). After this, when the dog is wet the air conditioner in the car can be used on the way to the veterinarian in order to gain both evaporative and radiation cooling (Brashear, 2015).

At the veterinarical clinic room temperatured intravenous therapy fluids are administered, both to cool the dog and to help with additional problems due to thermal injury. Other treatments include cool water enemas and gastric levage (Brashear, 2015). Cold water enemas or gastric levage however have been shown to not have a clear advantage over regular cool water baths (Reniker and Mann, 2012). To provide oxygen to the dog when the oxygen demand is increased during hyperthermia

a nasal catheter can be used, and low-flow oxygen distributed (Reniker and Mann, 2012).

2.5.2 Treatment of children

The interviewed paediatrician, see table 3.1 in section 3.2.2, summarised the treatments for hyperthermia as giving the child hydration and cooling the child. After being treated for hyperthermia the children usually do not suffer from any long term damages. Unconsciousness and death is something that is at an extreme and very rare.

The literature describes the treatment in more detail. According to Hoffman, 2001, for a child suffering from heat exhaustion, treatments include moving the patient to a cool environment for rest, and usually not any rapid cooling methods. The child is also re-hydrated, if the child is salt-depleted salty drinks and foods are to be provided (Hoffman, 2001).

If heat exhaustion leads to a heatstroke the treatment must be quick (Hoffman, 2001). The most prioritised treatment of children suffering from heatstroke is to remove the child from the hot environment, and to initiate cooling and supporting the organs to prevent any further deterioration. The cooling should be initiated immediately, before arriving to the hospital by placing the child in a cool and shady area (Chan and Mamat, 2015). Additionally the clothing should be removed and the skin can be sprayed with water. Ice can also be placed on the neck, axillae and groin. As soon as the child is stabilised transportation to a hospital must be arranged (Hoffman, 2001). If the child is suffering from heat cramps treatments include rest and muscle massage, and also re-hydration of the child (Hoffman, 2001).

Hoffman, 2001, describes that when arriving to the hospital the airways need to be protected against aspiration of vomitus or mucous, and intubation or mechanical ventilation could be used. Oxygen is important for the patients, since the heatstroke increases the consumption of oxygen. The rapid cooling also needs to continue (Hoffman, 2001).

Cooling methods can be categorised in internal and external cooling, and external cooling includes both immersion cooling and evaporative cooling. Evaporative cooling includes spraying water on the skin (Chan and Mamat, 2015). Immersion cooling is achieved when the patient is submerged in a bath (Gaudio and Grissom, 2015). A study has found that immersion cooling achieved through either ice water or cold water immersion gives a faster rate of cooling among adults compared to evaporative cooling. Issues with this can however be shivering as well as peripheral vasoconstriction, and ice on the skin can result in frostbite (Chan and Mamat, 2015).

Internal cooling methods include gastric, bladder and rectal lavage with cold water which can be performed with minimal invasion, and *peritoneal* and *thoracic* lavage.

These methods can bring down the temperature additionally (Chan and Mamat, 2015).

Once the core temperature of the body reaches 38-39°C cooling measures can stop. In addition to the cooling methods medications can be used, such as muscle relaxants and *neuroleptic* agents to prevent shivering. The organs that are failing also need intensive care besides cooling the patient (Chan and Mamat, 2015).

2.6 Rescuing a child or dog from a car

If you notice a child or dog in a car on a hot day, or if the child or dog seems to be in trouble the veterinarians and paediatrician interviewed, see table 3.1 in section 3.2.2, all stressed the importance of doing something. The procedure of rescuing a child or dog looks quite similar, and are described in the following two sections.

2.6.1 Rescuing a dog with heatstroke from a car

According to the interviewed veterinarians, see table 3.1 in section 3.2.2, if you notice a dog left in a car and you cannot find the owner you have to break the window if the dog seems to be in a bad condition. After this the dog needs to be cooled, moving it to a shady place and soaking it with wet towels or regular water was the suggested on site treatment. If the dog is really badly affected you might have to fully soak it in water. After that the veterinarians recommended you drive the dog to the veterinary clinic as fast as possible. It is however important to start the cooling procedure before driving to the veterinarian otherwise the hyperthermia will continue damaging the body as you drive to the clinic. For a flowchart of the procedure, see figure 2.5.

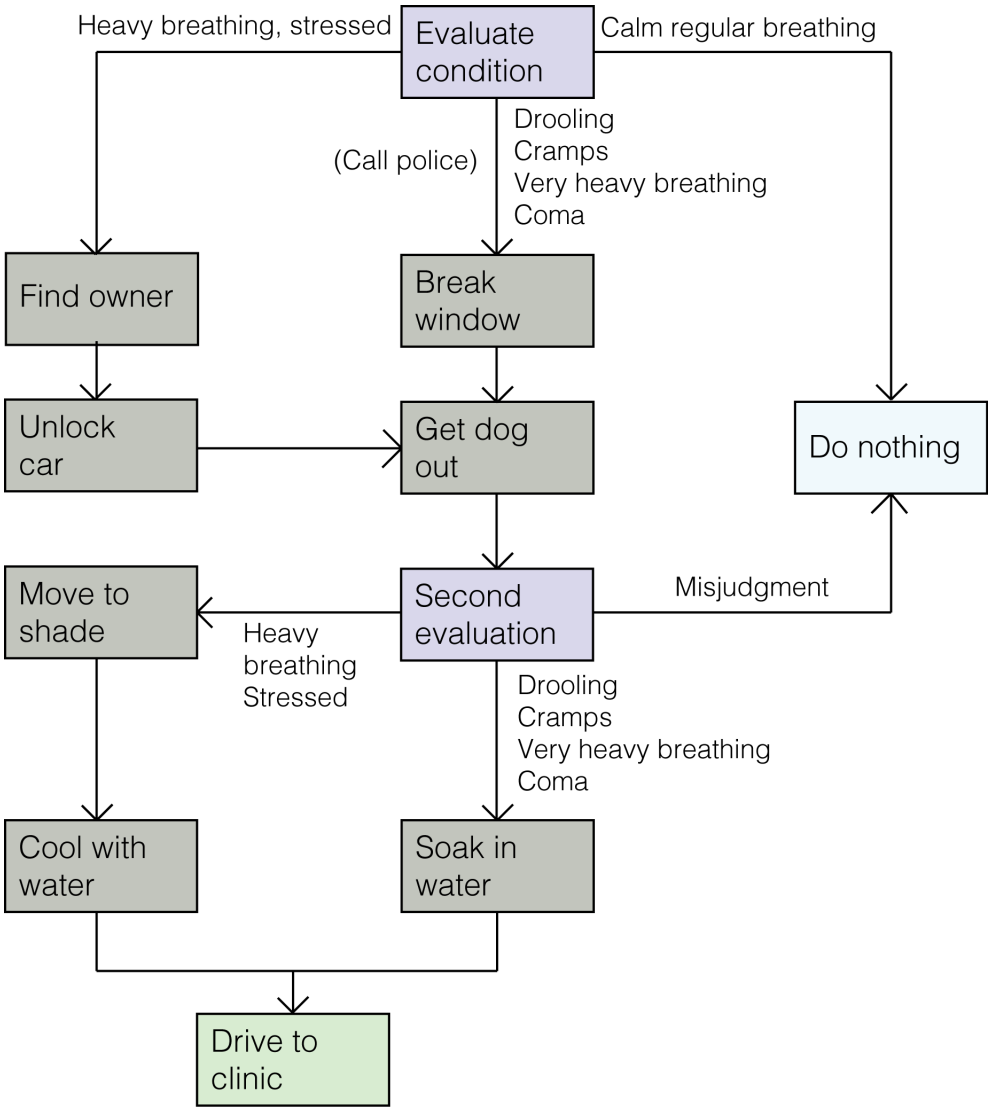


Figure 2.5: Flowchart describing procedure of rescuing a dog from a car

2.6.2 Rescuing a child with heatstroke from a car

According to the interviewed paediatrician, see table 3.1 in section 3.2.2, it is not recommended to leave children in the car at all. But if you notice a child left alone you need to take some sort of action by calling the police, contacting the parents, but not leaving the place without doing anything at all. When the child is removed from the hot car it needs cooling, you can put it in the shade and remove clothing. If it can drink you may provide hydration.

For a flowchart of the procedure, see figure 2.6. The different steps marked in bold are based on additional information found in the literature.

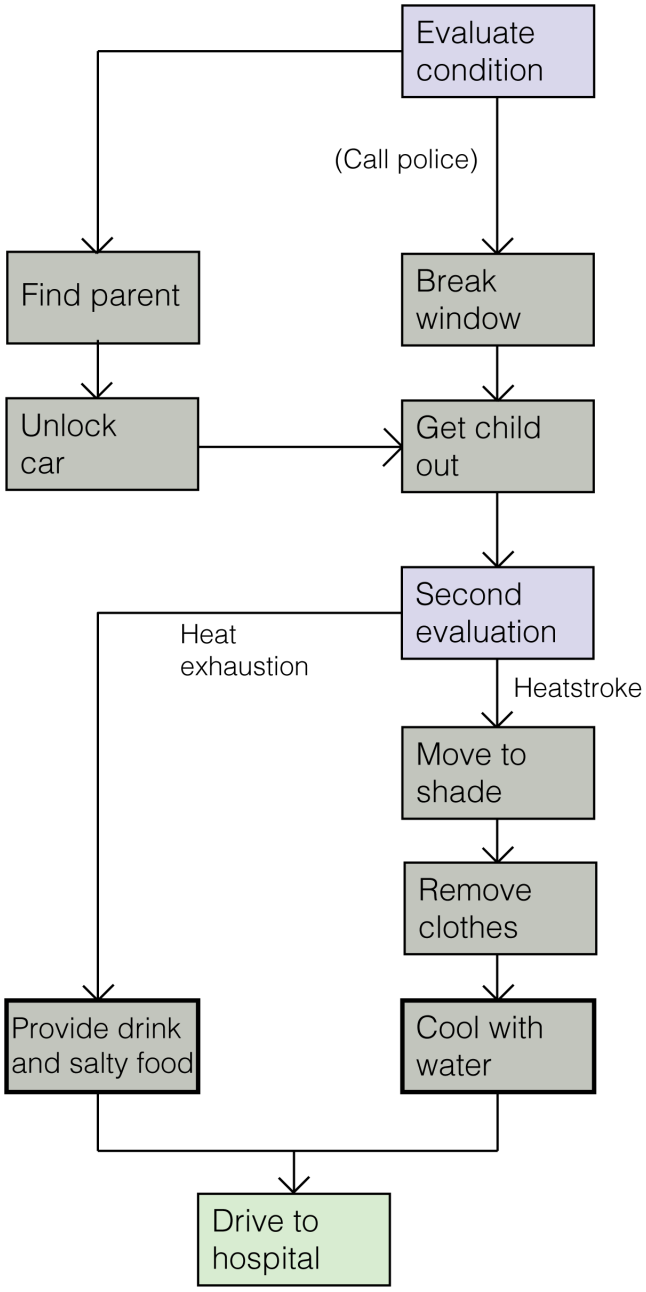


Figure 2.6: Flowchart describing procedure of rescuing a child from a car

2.7 Patient prognosis of heat illness

The consequences of heat illness are effects on the most vital organs for a living creature; the brain, heart, kidney, liver and also the skeletal muscle (Bruchim et al., 2009). Despite treatment in order to help a dog that is affected by heatstroke the consequences are serious complications. Furthermore except the complications the rate of fatality is high for the heat illness (Bruchim et al., 2006).

Severe hyperthermia among dogs that is not easy to treat (if even possible) results

in many various medical conditions. These conditions are *cerebral hypoperfusion* (decrease of blood supply to the brain), *neuronal necrosis* (cell injury), direct vascular damage, *cerebral edema* (brain edema), *hemorrhage* (bleeding), and "*multifocal vascular thrombosis* with tissue infarction that may lead to central nervous system abnormalities and death" (Bruchim et al., 2006). For heat illness it is noted that even though the dogs recover from the condition, they still may have remaining neurological deficits (Shell, 2007).

As described by Hoffman, 2001, among children that are affected by heatstroke the morbidity is high and the dysfunction of multiple organs is noted as quite common. Furthermore among children, a body temperature that is higher than 41,1°C in combination with severe health conditions as for instance coma and coagulation abnormalities mortality is regarded as high. Patients that regain their consciousness after 4-10 hours, may possibly develop conditions that affects the liver and the kidney that first worsens and then improves after 3-5 days. The patients that have decreased consciousness lasting for a shorter time than 3 hours are seen to recover in a shorter matter of time (Hoffman, 2001).

2.8 Hyperthermia affecting factors

Some factors affect the risk of hyperthermia among dogs and children, in the following sections these factors are described, as well as the effect possible precautiouns and preventive measures can have. The interviewed veterinarians and paediatrician did not know of any products aiming at preventing hyperthermia, so their effects are not discussed.

2.8.1 Hyperthermia affecting factors among dogs

The veterinarians interviewed, see table 3.1 in section 3.2.2, did not think that the size or breed of the dog would make much difference when the animal is left in a hot car. The most affecting factor was thought to be the temperature in the car. The size of the car was also thought as irrelevant, since even a larger car will heat up rapidly, making no significant difference to the dog inside. The humidity could however have some effect, making it harder for the dog to adjust it's body temperature. Leaving water for the dog in the car would not make much difference, only if it was ice cold it could make a slight difference to the hyperthermia, cooling the body slightly. In general one type of dog are very sensitive to heat, short nosed dogs (such as pugs). These dogs can suffer from hyperthermia from regular walks during hot days. Different types of greyhounds do however have an excellent ability to circulate the blood and are less sensitive to heat. But if the car gets up to 50°C it will not make any difference if it is a greyhound or a pug left in the car.

The veterinarians all agreed that lowering the windows would not make any significant difference to the heat in the car, only fully opening the trunk was seemed as having any effect. You need to achieve circulation of the air. The best solution however, according to the veterinarians, was to not leave the dog in the car at all.

But in addition to this they commented that would not work in people's everyday lives.

None of the interviewed veterinarians did know of any products aiming at solving the problem with dogs suffering from heatstroke or hyperthermia after being left in a hot car. One speculated if it existed cooling garments of some sort. The veterinarians try to inform the dog owners of the risks with cars and heat during summer.

2.8.2 Hyperthermia affecting factors among children

According to the interviewed paediatrician, see table 3.1 in section 3.2.2, a closed environment is a risk factor, no matter if it is a stroller or a car, especially if the child is tucked in with blankets. Also very small children are more dependent on the caregivers in terms of clothing. Older children may remove garments by themselves to cool down, but younger ones do not have this ability. At the age of about 5-6 years the child is probably able to tend to themselves enough to remove a seat belt and open the car door.

To prevent children from suffering from heatstroke and hyperthermia the children emergency staff inform parents about the risks with leaving them alone in cars, and how to properly dress the children during summer. The paediatrician did not know of any products aiming at solving the problem with children suffering from heatstroke or hyperthermia after being left in a hot car.

2.9 Circumstances of previous cases

A previous study by Bruchim et al., 2006, has shown that among 54 dogs admitted to the *Hebrew University Veterinary Medicine Teaching Hospital* suffering from heatstroke, 48% were cooled by their owners before admission, but the mortality had no significant difference due to this in the study. But there was a lack of statistical significance due to a variation of cooling methods. 79% of the cases occurred during the peak of hot season (Bruchim et al., 2006). Sometimes dogs are left inside of cars to guard it, and in other cases the owner simply leaves the dog in the car without realising the consequences (Gregory and Constantine, 1996).

A study by Guard and Gallagher, 2005 in the United States of 171 cases of children dying because of heat related illness caused by hot cars showed that 73% of the children were left in the car by their caregiver (and 28% were playing). Among the children left 54% were forgotten, 27% intentionally left and 18% had unclear circumstances. In a study by Booth et al., 2010, 231 deaths of children related to hot vehicles were studied, and 83,1% were left unattended. Among these, 13% were left intentionally and 75,5% were left unintentionally. In the rest of the cases the intentions were unclear.

In addition, a study by Ferrara et al., 2013 showed that among 16 cases of children suffering from heatstroke due to being left in cars 75% were left intentionally

and 18% unintentionally. In this study 13 out of the 16 cases had positive outcomes.

In the study by Guard and Gallagher, 2005 the children that died were of different ages, 34% were less than one year old, 23% were between 1-2 years old, 23% were between 2-3 years old and 15% were between 3-4 years old. Only 5% were older than four years old. The children in the cases where the child was left in the car by the caregiver, and not playing in the car, tended to be younger (Guard and Gallagher, 2005). The study by Booth et al., 2010, showed that 35,4% of the children were less than one year old, 60,4% were between 1-4 years old, 4,2% were between 5-9 years old and 0% were between 10-14 years old.

Also, in the study by Guard and Gallagher, 2005, of cases in the United States 83 women and 52 men were identified as responsible for leaving the child in the car. Booth et al., 2010, conclude in their study that in 8,7% of the cases both parents were responsible, and the mother being responsible in 33,3% of the cases, the father in 23,4% of the cases. Other related family were responsible in 19,1% of the cases, and daycare workers in 7,8%.

Among the children in the study by Guard and Gallagher, 2005, that were left the reasons included large family gatherings, moving or other upheaval. The parents who left their children on purpose did so because they did not want to disturb a sleeping child, not realising how hot the car would become. Some cases included the child being restrained in the car to allow the adults to work, sleep, drink or use drugs. Three children in the study were left because the parent was too intoxicated to notice the child being left. Almost half of the cases related to child care, 19% of the children were left by (mostly formally licenced) child care providers (Guard and Gallagher, 2005). In the study by Booth et al., 2010, it is described that among 100 of the 231 cases the caregiver did not remember to drop the child of at daycare, or the child was simply forgotten in the car. In 25,1% of the cases where the child was playing in the car the caregiver did not realise that the child was playing there. The most common circumstances of leaving the child in the vehicle including forgetting the child in the car (24,2%), forgetting to drop the child off at daycare (19%), the child was playing in the car (17,7%), unknown reasons (9,1%), child forgotten in car by daycare workers (6,9%) miss-communication between parents (6,5%), leaving the child in the car to make errands (6,1%) or to work (4,3%) (Booth et al., 2010).

Out of the 171 children in the study by Guard and Gallagher, 2005, twelve were left for more than 5 hours, and seven for more than 8 hours. The study by Booth et al., 2010 concludes that on average the children were 4,6 hours inside the car before found by someone, and the range was between 0,25 and 16 hours. One explanation of why children are left in cars could be that the working memory of the caregiver is affected by stress (Ferrara et al., 2013).

2.10 Working memory

Ferrara et al., 2013, speculate that children could be left in cars due to stress affecting the working memory of the caregiver. Sandom and Harvey, 2004, describe that the working memory, or short-term memory can only hold limited (between five and nine) amounts of information. The working memory holds information that is either discarded or transferred to the long-term memory. Failure in memory may cause errors, and when cognitive loads and demands on the memory are high error can also occur (Sandom and Harvey, 2004).

According to three studies by Klein and Boals, 2001, people who stated that they spent more time on stressful thoughts had worse working memory. Differences among individuals in working memory can be related to psychosocial factors (Klein and Boals, 2001).

2.11 Heat Ventilation Air Conditioning System

A heat ventilation air conditioning (HVAC) system in a car consists of five parts. These parts are; heater, cooler, humidity, purification and ventilation. The heater transfers heat and adds it while the cooler works in the opposite way, it removes the heat and by that maintains a cooler temperature. The humidity function adds or removes moisture inside the vehicle. The purification of the system uses a filter in order to purify the air inside and the ventilation is used in order to maintain a movement of the air inside the vehicle. The HVAC system can be adjusted within a range in order to maintain a pleasant temperature for occupants. The part of the HVAC system that allow the user to control the climate inside the vehicle is called the climate control (Daly, 2015).

2.12 Volvo XC90

Volvo XC90, see figure 2.7, is a luxury SUV carrying five to seven passengers, with a cargo space of 1868 litres. There is a dog gate that can be added to the car, keeping the dog safe even if the tailgate is opened. Two dog gates can be installed for keeping two dogs in the car. In addition *Volvo* provides a booster cushion that can be bought for older children between the ages of 3-10, allowing them to sit high enough in order to have a proper fitting safety belt (Volvo Cars, 2016d). The width and length of the *Volvo XC90* are 2008 and 4950 mm respectively (Volvo Cars, 2016c).

Volvo XC90 comes in one diesel or petrol version and one version with both a petrol engine and a hybrid battery in combination with an electrical engine (Volvo Cars, 2016c). The hybrid battery of the twin engine car has a power of 9,2 kWh (Volvo Cars Support, 2016c). The engine of the diesel or petrol version has a power of a minimum of 140 kW (Volvo Cars Support, 2016b).

The *Volvo XC90* is equipped with motion detection systems, which registers both motions and air currents inside of the car. The motion detection system is used as an alarm (Volvo Cars Support, 2016a).

Figure 2.7: Volvo XC90

Source: Danny Galvez, https://www.flickr.com/photos/66558050@N02/23248069044/ (License: https://creativecommons.org/licenses/by-sa/2.0/)

2.12.1 IntelliSafe

The *Volvo XC90* car has multiple safety systems, IntelliSafe, in order to support the driver and preventing accidents, as well as protecting you when an accident occurs (Volvo Cars, 2016a). Among the safety systems included in the car there is an adaptive cruising system, which utilises cameras to make sure you keep the distance to the car in front of you during queues. The car is equipped with 360°C cameras around the car, allowing for a bird's-eye view parking assistance. In addition to this the car is equipped with an automated parking assistance, automatically steering the car. This automatic steering is also used for keeping the car in the lane of the road if you start to veer out of it (Volvo Cars, 2016a).

The high beam of the car is automatically switched to low beam during nighttime driving when pedestrians, cyclists or other vehicles are close. Pedestrians and cyclists are also protected through warning systems that scans objects in front of you and warns for potential impacts and automatic braking where the car can brake if you are not able to do it in time *Volvo XC90*- also comes with a pedestrian airbag, seat belts that automatically tightens before an impact, and a safety cage protecting the passengers inside the car (Volvo Cars, 2016a).

2.12.2 Sensus

Volvo Sensus are mobile applications that connects your mobile phone to the car, and the car itself can be used as a wi-fi hotspot. The car itself also has integrated touch screens and voice controls (Volvo Cars, 2016b).

2.12.3 Volvo On Call

As a part of the *Volvo Sensus* package the *Volvo On Call* application allows you to control features of the car through your mobile phone, even when you are not inside of the car. The application allows you to send destinations to the car to use in the navigation system, and you can get access to the drive log (Volvo Cars Support, 2016d).

You can also use the application to locate your car on a map showing both your and the car's position. It is also possible to get the car to flash or honk to more easily locate it within a radius of 500 metres (Volvo Cars Support, 2016d).

Another functionality of the *Volvo On Call* includes warnings about anything in the car that needs your attention, the warnings are colour coded depending on urgency. The application can also inform you if the car is locked or not, and provide push notifications after 30 minutes of being unlocked. You can lock and unlock the car through the application (Volvo Cars Support, 2016d).

An additional function of the *Volvo On Call* application is remote heater start for car models with parking heaters. The car can be set to warm up at a specific time. The heater is then used in order to heat both the engine and the compartment, and depending on the outdoor temperature the heater starts in time to be ready at your selected departure time (Volvo Cars Support, 2016d).

In the *Volvo On Call* application there is also a function that allows the user to start the engine of the car through the application in order to cool or heat up the temperature inside of the car. This function is referred to as the Engine Remote Start (ERS). With the ERS it is possible to either cool down or heat up the car during 1-15 minutes. It is possible to use the ERS even though the car is equipped with a parking heater. During cold days the parking heater works more effectively than the ERS (Volvo Cars Support, 2016e).

3
Methods and implementation

In this chapter the methods used in the project as well as how they were implemented are described. The first section is a general description of the project structure. Following are sections based on the different phases of the project. The methods used are in most cases described first with a general description followed by the implementation in the project.

3.1 Project structure

The general project layout for this master thesis is described in figure 3.1. The project consists of five phases, the first four being iterated as necessary. During each phase requirements on different levels of detail are set, and testing occurs if necessary. As the development goes on the level of detail for both concepts, requirements and testing increases. When the level of detail increases fewer and fewer concepts are developed, resulting in one final concept. In the first concept phase subsystem concepts are developed, in the second full system concepts. The pre-study results in general and user needs describing the medical needs and user related needs of the product. The subsystem concept phase results in requirements of the full system, and the full system concept phase results in element requirements for the selected final system which is further developed in the detailed design phase. Finally, in the end of the detailed design phase detailed element requirements are presented.

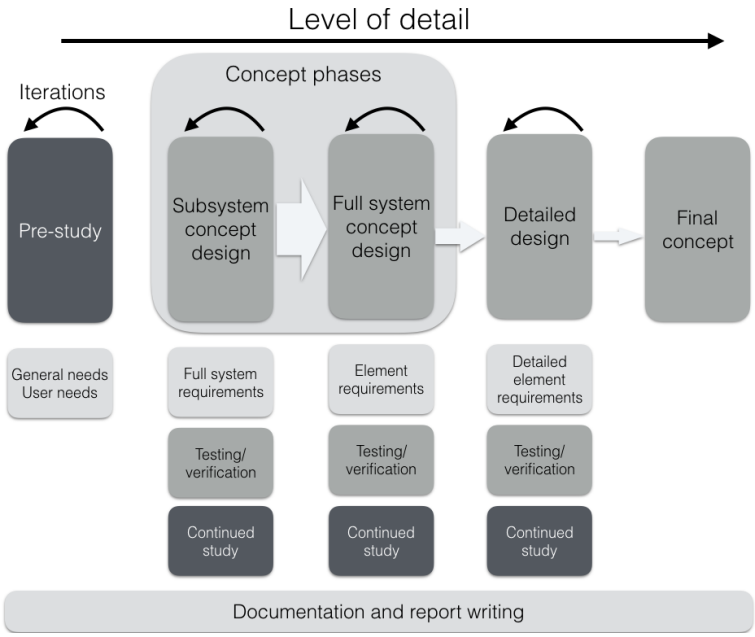


Figure 3.1: Process description

3.2 Pre-study

In order to understand the problem, both in the medical, user and technical perspective a pre-study was conducted. It consists of a secondary research including a literature study to understand the problem based on previous publications and a benchmark where existing products on the market and patents are analysed. Finally interviews and questionnaires were conducted in order to gather new data for analysis of the problem. With the results of the pre-study user and general needs were listed, these needs were verified with a questionnaire. Personas were also created to support further design work.

3.2.1 Secondary research

Secondary research includes using data gathered by a second party. It is cheap, quick and can be used both with internal and external information. External information includes data gathered by governmental agencies, information from commercial vendors and public information (McQuarrie, 2012).

Most secondary research conducted in the project was external, with the subject being researched through literature to get a basis for the further interviews and questionnaire. The focus was on the medical and user related issues and on the technical specifications related to *Volvo* cars. A benchmark was also conducted to investigate existing products and patents.

Literature study

Literature from public data sources includes literature published in news papers and magazines, mostly available online for free, except for some sources that are located in specialised databases (McQuarrie, 2012).

In order to gather literature on the issue of hyperthermia among children and dogs left in cars, online based literature were the primary source of information. Most of the search for literature was conducted through *Chalmers library (www.lib.chalmers.se)*, *Swedish University of Agricultural Sciences (SLU) library* and *PubMed (http://www.ncbi.nlm.nih.gov/pubmed)* using search phrases such as *hyperthermia*, *heatstroke*, *dog* or *child* and *car*. In addition *Google search engine* (www.google.com) and *Google Scholar (scholar.google.com)* were used, with the same search phrases.

Some literature were accessed through specialised data bases only accessible by veterinarians or physicians, such as the *Associate Database - VIN* and *UpToDate*, *www.uptodate.com* and articles from these were acquired through veterinarians and physicians interviewed in the project.

Car study

The target car, *Volvo XC90* was mainly researched through the *Volvo* homepage, *(www.volvocars.com)*, and their support page *(www.support.volvocars.com)*. Also, information about heat ventilation air conditioning systems in cars were researched through *Chalmers library (www.lib.chalmers.se)*.

Benchmark

A benchmark is performed to gain an understanding of the current existing and competing products, and is important to position a new product on the market. It also provides design ideas. In a benchmark the products can be compared to the perceived satisfaction of customer needs, or towards measurable metrics (Ulrich and Eppinger, 2012).

In order to investigate the current products on the market and patents a benchmark was conducted. Online searches were made on *Google search engine (www.google.com)* for regular webpages reviewing or retailing products such as alarms for preventing hyperthermia. Search phrases used include *dog/child, hot, car, product* In addition a patent search were conducted through *Google Patents (patents.google.com)* with the search phrases *dog/child, car, hyperthermia/ heatstroke*. The products were compared based on features rather than metrics suggested by Ulrich and Eppinger, 2012.

3.2.2 Interviews

An interview can be conducted either as structured, semi-structured or unstructured. During a semi-structured interview the investigator has already decided about a set

of topics that are considered relevant, using prompts to gain desired answers ensuring that the topic is covered. The respondents still have the opportunity to emphasise important topics. Interviews also have a small risk of the respondent misinterpreting the question (Jordan, 1998). Despite being time consuming, interviews give access to data that can be difficult to gain through observations or written responses (Philips and Stawarski, 2008).

Interviews were conducted in person with both physicians and veterinarians in order to understand the medical issues of the problem. In order to get a qualitative understanding of the user related problems interviews with parents and dog owners were conducted. The interviews were semi-structured, with specific questions to be responded according to a structured interview, but still with room for follow-up questions in order to get additional information according to an unstructured interview.

Three veterinarians and one physician were interviewed, see table 3.1 below. The full translated medical interview guides can be seen in appendix (see appendix A and B). Since the questions were of medical nature the interview sample was selected based on available experts in the Gothenburg area. Also, since the veterinarians and physicians are not the main target group of the product but rather a source of medical information the representativeness of the sample was not considered. For convenience of the respondent the interviews were conducted in Swedish.

Table 3.1: Medical interviews

Name	Profession	Place of work	Experience	Specialisation
V1	Veterinarian	Anicura Västra Frölunda	15 years	Specialist in dog and cat diseases
P1	Physician	Drottning Silvias barn- och ungdomssjukhus	20 years	Paediatrician
V2	Veterinarian	Evidensia Kållered	31 years	Specialist in dog and cat diseases
V3	Veterinarian	Evidensia Kållered	30 years	Specialist in dog and cat diseases

Two dog owners and two parents were interviewed, see table 3.2. The full translated interview guide can be found in appendix (see appendix C). The respondents were chosen based on available dog owners and parents in the Gothenburg area, and as with the veterinarians and physicians the interviews were conducted in Swedish for the convenience of the respondents. The interviews were recorded, transcribed and analysed using the KJ method.

Table 3.2: Interviews with dog owners and parents

Respondent number	Age	Dog owner/parent	Type of car
IP1	34	Parent	Combi car
IP2	27	Parent	Combi and small car
IP3	25	Dog owner	Combi car
IP4	25	Dog owner	Hatchback car

3.2.3 KJ method

The KJ method is a method developed by a Japanese anthropologist named *Jiro Kawakita*. The method is used through dividing up qualitative data into chunks that is specified by the themes of the data itself. This analysis method is useful when handling data from interviews, focus groups and several other applications (Courage and Baxter, 2005).

The KJ method was implemented in order to structure the data received from the interviews with the users (dog owners and parents). The data that concerned the same subject in the interviews were divided up into chunks, making it more easy to interpret and understand what the overall thoughts were about each subject. Except for the interviews with dog owners and parents, the information related to human behaviour obtained when interviewing the veterinarians and the paediatrician were also included in the different chunks formed by the user answers.

3.2.4 Questionnaire

A questionnaire is a list with printed questions, either with fixed responses or with open-ended answers. When creating a questionnaire, reliability (whether the questionnaire is repeatable) and validity (whether the questionnaire gives answers to the issue to be investigated) are important to consider. When these are confirmed the questionnaire has the advantage that it can be distributed to many persons for a low cost (Jordan, 1998). The questionnaire, with a larger number of respondents, highlights the distributions of answers (McQuarrie, 2012).

In order to get a quantitative data on the user related aspects of the problem two questionnaires were used. One aimed towards investigating the aspects of the problem related to cars and children and the other towards cars and dogs. Checklists with multiple answers selectable and multiple-choice questions with one answer selectable were the main type of questions. The sample used for the questionnaire was primarily aimed towards the demographic profile of parents and/or dog owners or other persons who have at some point left a child or a dog in a car. To make sure that a wide range of dog owners were covered extra efforts were made to reach the demographic group of elderly dog owners. The questionnaires were secondarily aimed towards people who have seen a dog or a child left in a car.

The questionnaires were web-based and posted on different Swedish online forums (see appendix F). Since *Volvo* is the most sold car brand in Sweden (Statistics Sweden, 2015), and produced in Sweden the questionnaires were written in Swedish aiming mostly at the Swedish market. Also previous literature on the topic has covered behaviour related to United States and other international markets already. The complete questionnaires can be found in appendix (see appendix D and E).

3.2.5 Personas

Personas are used as a representation of the target used, conveying specific information about users. They provide a common way of talking about users, and help to design for the specified users. Personas also raise empathy for the users, helping the team becoming more user focused. It is best if the persona is built from documentation, but assumptions is also sufficient. In order to make a difference to the work the persona needs to be shared and come to life in the minds of the team, not only documented. They can be valuable if created quickly, but to gain their full value investment of time is required (Adlin and Pruitt, 2010).

In the project personas were created to keep the actual user in mind. The interviewed users were parents and dog owners driving cars, but not drivers of *Volvo XC90*. In order to get an understanding of the real users, the created personas were also based on the target group of the car, using elements from the dog owners and parents interviewed.

3.2.6 Expression Association Web

The Expression Association Web includes one adjective describing the general characteristics of a persona, and multiple adjectives describing the product expressions and message of the product according to the persona and context of the product (Wikström, 2012).

In the project the Expression Association Web was adapted not including the persona description, since multiple personas were used, but only the product message. It was used when creating Semantic differential in the subsystem concept design phase, as well as an inspiration in the design work in general.

3.2.7 Inspiration Board

An inspiration board is used in the concept development for personal use within the group. It can for example be used to create technical solutions or to develop an idea further according to desired experience or expressions. The inspiration board can contain for example other products in the chosen context, details and brands (Wikström, 2012).

The Inspiration Board was created based on the findings in the pre-study and used in the later design phases when creating and further developing full system concepts, in order to keep the desired experience of the final product or system in mind.

3.3 Concept phases

The concept phases range from subsystem concepts to full system concepts, with the methods used being rather similar in the phases. In this section the methods for both the subsystem and full system concept design phases are described.

In the subsystem phase brainstorming was used to give a broad range of concepts. In addition a scatter plot was used to investigate the solution space. In the full system phase an adapted Morphological Matrix was used, combining the created subsystem concepts into full systems. Brainstorming was also used, in order to create additional full systems. The concepts were screened and reviewed based on the strengths and weaknesses both using a Pugh Matrix and a Kesselring. In order to let users review the concepts a Semantic differential was used.

3.3.1 Brainstorming

Brainstorming is a type of internal search where previous knowledge is turned into ideas. The process can be both individual or performed as a group. During a brainstorming session it is important to suspend judgement, in order to not limit the amount of ideas generated. The quantity is important rather than the quality of the ideas, and even infeasible ideas are welcome. To be able to discuss the ideas it is important to use not only words but graphical and physical media. There are different suggestions for techniques to stimulate thinking, such as making analogies and using different stimuli (Ulrich and Eppinger, 2012).

The brainstorming method was adapted in different phases and was conducted by the project group. First a general broad brainstorming generated subsystem concepts. Later in the full system concept phase additional concepts were created with brainstorming in those cases where promising subsystems were not possible to combine with already existing ideas. In the final detailed design phase brainstorming was used to design the feature in the application used in the system.

3.3.2 Scatter plot

A scatter plot is a representation of the relationship between two variables, in two dimensions, where the values are plotted on a horisontal x-axis and a vertical y-axis. It can be used to evaluate correlation.

In the project a scatter plot was used to evaluate the solutions generated in the subsystem concept phase. On the x-axis the concepts were plotted against how proactive-reactive they were, and on the y-axis if they were more controlled by the human or car. The result showed if there was parts of the solution space that were not covered.

3.3.3 Morphological Matrix

In order to systematically combine different sub-functions in a logical way a Morphological Matrix can be used. The sub-functions with the different solutions are entered in rows of a table. These different functions are combined with one solution from each row. Only compatible solutions should be combined (Pahl and Beitz, 1996).

An adapted version of the Morphological Matrix was used used in the full system concept design phase after sorting the initial subsystem solutions into categories possible to combine. One or many solutions were selected from each category to create full system concepts.

3.3.4 Pugh Matrix

The Pugh Matrix is a way of comparing concepts against each other with a baseline as reference, which could either be the current solution or a middle-of-the-road concept. It is also usable to create hybrid concepts to improve the existing ones. The concepts are evaluated against different criteria plotted at each row in the matrix. Each concept is then ranked for each criteria against the baseline, a plus marks that the concept is better than the baseline, a minus that it is worse. If there is no difference it is assigned an S. The amount of pluses, minuses and S are summarised for each concept and the sum is presented at the bottom of the matrix. Then the concepts are ranked based on the summarised score. The Pugh Matrix does not provide an absolute mathematical truth about which concept is best, but a qualitative way of discussing the concepts and improve them. It is also possible to ad weighting to each criteria, this does however not give an absolute truth, discussion is still important. When the matrix is finished the concepts are either merged into new concepts based on the best features or developed further (Silverstein, Samuel, and DeCarlo, 2009).

The Pugh Matrix was used in the full system concept design phase in order to give an initial view on the concepts created, the strengths and weaknesses and relate these to the customer and general needs elicited in the pre-study. The results were used to eliminate concepts not fulfilling the needs at a satisfying level.

3.3.5 Semantic differential

A Semantic differential is a way of comparing a product with competiting products based on the strengths and weaknesses of the product. Respondents describe the chosen products by selecting an alternative on a scale of a pair of words, for example traditional - innovative, describing the product. The result is plotted on a scale as an image (Law, 2009).

The Semantic differential (see appendix Q) was used in user interviews (see appendix P for interview guide) to get user opinions on full system concepts. The words selected were based on the previously created Expression Association Web and the

scales were mixed and reversed during the interviews not to give the respondents hints of the desired answers.

Two dog owners and two parents were interviewed in unstructured interviews, see table 3.3. The concepts were described to the participants and the participants were asked to fill in the scale while thinking aloud, discussing the concepts based on the answers on the scales.

Table 3.3: Semantic differential concept interviews

Respondent number	Age	Dog owner/parent	Type of car
IP5	38	Parent	SUV and Sedan car
IP6	33	Dog owner	Combi car
IP7	42	Parent	Hatchback car
IP8	29	Dog owner	Combi car

3.3.6 Kesselring method

The Kesselring method is used in order to score different solution alternatives. The method uses selected criteria with weighted importance for each criteria. The evaluation is performed through a matrix where the selected criteria are placed at the rows with respective importance and the different solution alternatives are placed at the columns of the matrix. In the matrix there is a theoretical concept scoring maximal points on the defined criteria and hence can be seen as an ideal solution alternative. Each of the solution alternatives are rated based on how well they fulfil each criteria. For each of the criteria a total score is calculated through multiplying the importance with the rating for each of the criteria. Continuously for each of the solution alternative the calculated total scores for each of the different criteria are summarised. In order to get a clear picture of which of the solution alternatives that got the highest ranking, the sum of the calculated total scores are divided by the sum of the total score of the ideal solution (Johannesson, Persson, and Pettersson, 2004).

The Kesselring method was used in order to evaluate the strengths and weaknesses of the developed full system concepts and to rate them based on pre-defined system requirements. This was used after selecting promising concepts with the Pugh Matrix, giving a more correct picture of the strengths and weaknesses compared to the first evaluation.

3.4 Detailed design

In the detailed design phase the different elements of the final selected concept were evaluated and developed. Evaluation and development included testing, calculations and research through communication with experts in different fields, manufacturers and the Internet.

3.4.1 Evaluation of air conditioner

The evaluation of the air conditioner (AC) in the selected system was performed through calculations based on the power consumption of the AC. This was done through estimating if both the battery power of the hybrid car and the engine power of the regular car are able to provide enough power to have the AC cool the car. Necessary information was provided through research at *Volvo's support page (http://support.volvocars.com/se/pages/default.aspx)*, through talking with an expert in air conditioning systems as well as through articles from *Chalmers library (www.lib.chalmers.se)* regarding the power consumption of general AC systems.

Except for the calculations, the AC was evaluated through discussions with an expert in the field if it would be feasible to use a system that would power the AC when it got hot inside the car and also remote start the AC through the car computer. Moreover the function to remote start the AC in the car was researched on the *Volvo support page (http://support.volvocars.com/se/pages/default.aspx)*.

3.4.2 Evaluation of solar panel

To determine the necessary area of solar panels required to power the AC calculations were made, using data of the power generated on typical solar panels used in Swedish conditions from *Nationalencyclopedin (www.ne.se)*. The required power were based on the results from the literature study performed when researching the AC through *Chalmers library (www.lib.chalmers.se)*.

3.4.3 Test of infrared camera

When evaluating the possibility to use an infrared camera to detect children and dogs left in cars a test was conducted. During the test an infrared camera, *Flir A20M*, was borrowed from *Chalmers University of Technology*. The camera was placed in a *Volvo XC60* car and pictures were taken on a human and different dogs at different temperatures and with different camera settings. The study aimed at evaluating the risk of the human and the dogs being invisible to the camera at certain temperatures. The person participating in the test was an adult female with regular body temperature and the dogs that participated were of different breeds, see table 3.4.

Table 3.4: Dogs photographed with infrared camera

Dog number	Breed	Fur type	Size	Color
Dog1	Shetland Sheepdog	Long double coat	35 cm	Black
Dog2	Podengo portugues pequeno	Short smooth-haired	20-30 cm	Light
Dog3	Miniature Schnauzer/ Cocker Spaniel	Long wirehaired	35 cm	Black

3.4.4 Computer Aided Design

Computer Aided Design (CAD) is the usage of a computer within construction work either in two or three dimensions. When working with three dimensions a model is created either with wires, surfaces or solids. Surface modelling is used for design of curved surfaces, such as consumer goods (Pärletun, 2016).

In order to decide the placement of the infrared cameras inside of the car a mock-up CAD was used. The model was created with solid modelling in *Catia V5* and surface modelling in *Autodesk Alias AutoStudio 2016* based on measurements and photographs taken inside a *Volvo XC90* at a local car dealer and measurements provided in a brochure by *Volvo*. Based on research on *Google search engine (www.google.com)* dog cages and child car seats were selected for modelling. Two dog cages of the most common brands in Sweden, *MIM Construction (www.mim.se)* and *Proline (www.4pets-products.com/!4pets-proline-en/c19f9)*, were selected and modelled according to reference images and measurements. The dog cages that were selected were of a large size, and had the most areas that were fully covered among the found cages. The child car seats were based on the research on *Google search engine (www.google.com)*, and due to the similarities between the different variants one generalised baby car seat with a hood, and one generalised child car seat for children up to the age of five were modelled.

The finished mock-up was used in *Autodesk Alias AutoStudio 2016*, where cameras were placed inside of the car to provide views on the different necessary areas. One set-up with camera utilised the current common maximal angle of view of 90° provided by leading manufacturer *Flir (www.flir.com)*. A second set-up was created with the goal of minimising the amount of cameras needed, allowing larger angle of views.

3.4.5 Development of mobile application feature

The mobile application feature was created mostly using brainstorming. The *Volvo On Call* design was used as a foundation and used as inspiration for both the

symbols and information presented in the feature. The feature was created as a mock-up based on images from the existing mobile application. The pictures on the integrated feature were created using *Adobe Illustrator CS4* and by using print screens of the currently existing mobile application as a foundation.

3.4.6 Usability test of mobile application

Usability refers to how easy a product is to use. Lack of usability can cause problems that are everything between annoying and life-threatening, cause lower product sales, less productivity among users or be a safety issue. In short, usability can be described as four components, guessability (using a product for the first time), learnability (using the product after having used it before), experienced user performance (the usability for experienced users), and system potential (the optimal level of effectiveness, efficiency and satisfaction when using the product) (Jordan, 1998).

When evaluating usability usually the methods involves user participants, since this is an advantage. One method is think aloud protocols, where the user is asked to use the interface while thinking aloud while performing tasks. This gives not only a view of what problems the user has with the interface, but also the reason for the problems (Jordan, 1998).

In order to investigate the possibility to use the *Volvo On Call* application as a host for the developed system the present *Volvo On Call* application was tested through an usability test (see appendix R for the interview guide) on the *iPhone* version of the application demo. The goal of the test was to investigate the learnability and guessability of the application, and to detect any large usability problems that could affect the possibility to integrate the developed system in the application. The test consisted of four different scenarios containing different tasks that are possible to perform by using the mobile application. Before the scenarios a short questionnaire (see appendix S) on how well the user understood the symbols in the current mobile application was performed. Six different persons participated in the test all with normal eye sight or wearing glasses or contact lenses, see table 3.5. During the scenarios the user performed tasks with the applications, while being asked to think aloud.

Table 3.5: Volvo On Call interface test participants

Test participant number	Smart phone experience	Experience of functions in new cars	General technical knowledge about cars	Used operative system	Used Volvo On Call before
TP1	Average	Little	Little	Android	No
TP2	Very much	Much	Average	Android	No
TP3	Very much	Average	Average	iOS	Yes
TP4	Average	None	Little	Android	No
TP5	Very much	None	Average	Android	No
TP6	Very much	Average	Average	Android	No

3.4.7 Flowchart function description of software

A flowchart can be described as a graphical representation of low level which represents the structure of a program. The emphasis is put on control flow and primitive actions. Various shaped boxes and directed arcs are used, and within the boxes notations are used to describe the action or decision (Butterfield and Ngondi, 2016).

When giving suggestions for the functionality of the software a simple flowchart was used. No standards were followed, but the goal was to visualise the system and software in a simple way.

3.4.8 Failure Mode and Effect Analysis

The Failure Mode and Effect Analysis (FMEA) is a method that can be used in order to relate the potential failure modes of a construction with the potential effects of the failures. In a systematic way the potential failure modes, its causes and the effects of it is decided and presented. If there are any current process controls of the different failure modes, these as well are presented. Continuously the different defined failure modes are rated based on their severity (with 1 being not severe and 10 being very severe), occurrence (with 1 being remote possibility and 10 being high possibility) and detectability (with 1 being high detectability and 10 being low detectability). After rating these three factors they are multiplied with each order, and the number received from this calculation becomes the risk priority number (RPN). The RPN number is a measure for how serious the detected failure mode is for the analysed construction, a larger RPN value results in a worse fault. Furthermore, for each failure mode, recommended actions and the person being responsible for the actions are defined (Johansson, 2003).

The implementation of the FMEA started with brainstorming different potential failure modes, their potential effects and their causes. The detected failure modes got ranked and the RPN value was calculated (see appendix T for the FMEA). Continuously recommended actions and the person being responsible for it was defined.

The created FMEA was not a complete FMEA, but rather an interpretation of it using only relevant parts of the full version. The parts related to the results of the actions supposedly taken were neglected. The FMEA was performed on the whole system, not on individual elements of it.

3.5 Needs and requirements

According to Ulrich and Eppinger, 2012, those in direct control of the details, such as industrial designers and engineers, need to be in direct interaction with the customers in order to make correct trade-offs. Interaction with the customers is important even if they are not able to express their latent needs. Customer needs are not dependent on the product that is chosen to be developed, and should be identified without that knowledge. Three methods are common for eliciting customer needs:

- Interviews
- Focus groups
- Observations

Requirements depend on the developed product and consist of a metric (requirement) and a value with a unit. The value may take form as a number, inequality or range. When the metric is a statement that is either fulfilled or not the value becomes yes or no, with the unit binary. An ideal target is set for the requirements using for examples exact values, a range or a set of values (Ulrich and Eppinger, 2012).

In the project needs are represented by user needs and general needs, both based on the results from the pre-study. The user needs include the needs of the parents and dog owners, the possible users and customers while the general needs are based on medical information from the literature study and medical interviews. After small subsystem concepts have been presented a list of full system requirements is developed in order to be used when designing full systems. These full system requirements are on a general level not including target values. After full systems have been designed, and combined into a final concept element requirements for each element in the concept are listed, also on a general level not including target values. These are used in the detailed design of the final concept, during which the element requirements are developed into detailed element requirements, the final requirements of the developed system. The detailed element requirements are also based on the elements of the system, but with target values after being researched during the detailed design phase.

3.5.1 Establishing needs and requirements importance

In order to make trade-offs in product design it is important to have a sense of the relative importance of the needs. This can either be achieved with consensus of the team members based on experience with the users, or by a customer survey. It is

suggested by Ulrich and Eppinger, 2012, to do a survey since it is important and worth the time. A limit to the amount of needs to address in the survey is about 50. The users get to rate the different needs on a scale of, for example, 1 to 5 (Ulrich and Eppinger, 2012).

To verify the user needs and to some extent general needs and full system requirements in the project a questionnaire (see appendix N) containing 19 needs and requirements were posted on the different forums (see appendix F). The data was summarised and the mean value (rounded up to nearest integer) for each need/requirement was set as the relative importance, with some adjustments made.

4

Pre-study

In this chapter the results from the pre-study are presented and analysed, the pre-study as part of the whole project process can be seen in figure 4.1. However, the results from the literature study and medical interviews conducted during the pre-study can be found in chapter 2, where the theory is presented.

First the existing products and patents are presented, then the results from the user interviews and finally the results from the questionnaires evaluating the current situation. The results are used in two different needs lists, one general summarising results from the benchmark as well as the literature study and medical interviews presented in chapter 2, and one with user needs, summarising the results from the user interviews and questionnaires. The needs are weighted according to their relative importance based on a survey among users, and interpretations by the project group. A persona, image board and expression association web were created to aid the further development work, also based on the results from the findings in the pre-study. At the end of the chapter the results of the pre-study are summarised.

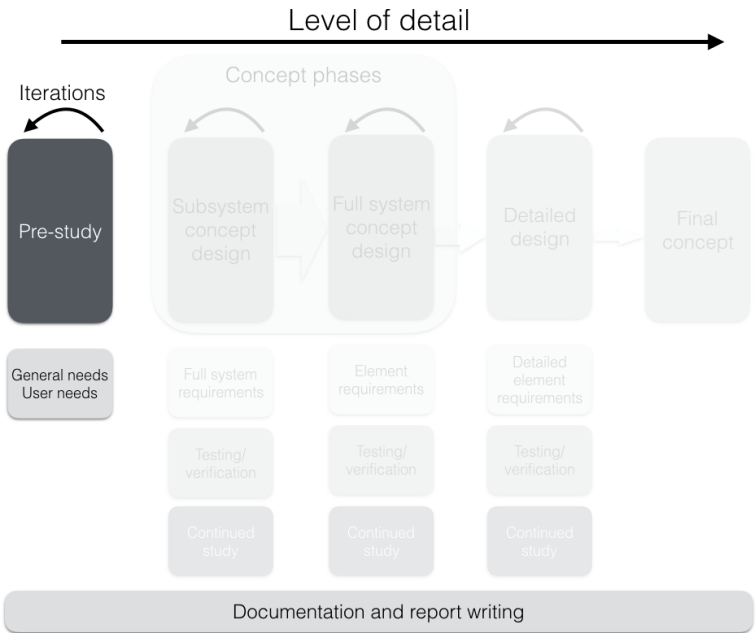


Figure 4.1: Process phase pre-study

4.1 Existing products and patents

Several different existing products were found and compared. These products are summarised in a table in which the different existing products were analysed against pre-defined definitions. These definitions included for instance; what type of market it is aimed at, what type of product it is, its functionality and its technical details (see appendix G). During the search many of the products found had the same functionality, in many cases using a mobile phone application and some kind of alarm. Among the products found there were 13 of the total amount of products that were selected and compared in the benchmark, both for the dog and the child application. The similar products on the market were excluded.

The criteria regarding what type of product it is, was divided into four different types based on the most common variants. These include; alarms that sounds when the driver leaves the car, alarms that sounds when the driver has arrived to its destination, alarms that reacts whether it becomes hotter or cooler and other types of products that function differently. In the benchmark it was noted that there are several products that use alarms as a method in order to prevent dangerous situations and not that many other types of products. The content of the benchmark illustrates the spread of the existing products in this area right now.

Among the patents found during the patent search, 14 patents where selected and studied to get an overview of other solutions to the problem. As with the product many more exist, but were similar in design and therefore excluded. The patents like the products include mostly alarms when the car gets too hot, but also alarms that prevented the user from forgetting the passenger in the car. Two patents aims at cooling a dog left in a car, and one consisted of a combined alarm and cooling product that cools the child if necessary. The complete list of patents studied can be found in appendix (see appendix H).

4.2 General needs

The general needs are a result of the literature study and medical interviews presented in chapter 2, and the benchmark. The importance of some of the needs were based on the results from a survey answered by 30 dog owners and parents in total (see appendix O), but interpreted by the project group to give a more accurate number. The importance of the needs that were not based on the survey were defined by the project group. See the general needs list including the importance below.

Prevents children and dogs from suffering from heatstroke/hyperthermia in cars
- Ensures no permanent effect on health condition [5]
- Ensures that dog body temperature does not reach 41 degrees [5]
- Ensures that child body temperature does not reach 40 degrees [5]

Is usable in different environments
- Is usable in all weather conditions [4]

- Is usable all around the year [4]

Works in different use situations
- Functions with the car ignition turned off [4]
- Functions without reliance on the operators working memory [3]
- Functions without a present operator [5]

4.3 User interviews

In the following sections the results from the interviews with parents and dog owners are summarised. The sections concern different topics related to attitudes towards leaving children and dogs in cars. The foundation for the results presented is the outcome of the performed KJ-analysis.

4.3.1 Dogs and children in cars

In this section the issues related to the situations when dogs and children are left and the placement in the car are described. The users interviewed did not commonly leave their children or dogs in cars, so they also speculated on other parents and dog owners behaviours.

Travelling with a dog or child

> When I'm about to go somewhere and she is going with me, like for instance when I'm going to the stable.
>
> IP 4

The majority of the respondents answered that they usually had their dog and/or child with them in the car when they were about to go for a longer trip, for instance when travelling to another city or the stable in the case for one respondent. One of the respondents that had children mentioned that they usually did not bring their children when they were going to use the car for grocery shopping and instead left them at home. One veterinary also mentioned that it is not legal for the police to keep the police dogs in the car for the amount of time that the police needs, since the area that they are being kept in is legally too small for the dog, and that this causes the Swedish police problems.

Placement in car

Both of the interviewed dog owners state that their dogs are transported in the back seat with a harness that is fastened in the regular seat belt. A veterinarian, however, estimated that most dogs either ride in the trunk of the car or in the lap of the owner. One of the interviewed parents stated that their child is placed in a rear-facing child seat in the back seat, and the other parent (who has three kids) state that the eldest travels in the middle of the back seat, with a car seat for older children, the youngest is placed in the front and the middle child in the back on one of the side - both of them in rear-facing child seats.

4.3.2 Leaving dogs or children in a car

As seen in the literature, see chapter 2, children and dogs are both left alone on purpose and forgotten in cars. In this section the attitudes of the interviewed parents and dog owners related to the issue are described, as well as their thoughts on other peoples attitudes.

Reasons for leaving dog or child in the car

The respondents, both parents and dog owners did not leave their dogs or children in the car during any significant time at all. When asked what would make them leave the child or dog making quick errands was the possible case, during which the respondents would hurry. The primary concern for not leaving the child or dog was other reasons than heat, such as stress in the child or dog. The interviewed parents felt that they would only consider leaving their children in the car within sight.

> Yeah, that's something that one normally is trying to avoid, since we are aware that it could be a trauma for the kids, even though they don't get affected by heat illness.
>
> IP 1

> Yes, absolutely. I believe that many think that it is for a short time and that it then doesn't matter.
>
> IP 3

When asked why they thought other people leave dogs or children in cars the respondents speculated that it most probably occur when making errands, and the dog or child gets to wait in the car. Especially parents can be stressed, and unpredicted situations could occur where you have to leave the child in the car. One parent mentioned that an issue that causes parents to leave the child in the car could be if the child has trouble sleeping, and finally has felt asleep in the car. Then the parent would not want to disturb the child by removing it from the car. One veterinarian also stated that in many cases you cannot drive home with your dog before going to the grocery store or making other errands, therefore the dog might be left in the car.

The personality of the dog or child would probably also affect the decision to leave it alone in the car. One respondent stated that their dog is nervous and gets stressed when being left alone in a car. Therefore one of the owners always stays in the car with the dog. Also, some dogs could be easier to keep in the car rather than leaving them home alone in the apartment. This could also be a case if the dog is loud when being left alone, and the owner do not want to disturb the neighbours. As stated above parents of children that are loud and screams a lot might be more keen on leaving them in the car when the child is finally asleep.

Forgetting the dog or child in a car

> Yes, that's hard to admit but yes, I'm honest, yes.
>
> IP 4

Regarding the interview question about whether the interviewee have forgotten their dog or child in a car or not there were mixed answers. One person that was interviewed remembered and admitted that they had forgotten their dog in the car. When being asked why this situation could occur they believed it was mostly because of stress. The reason for why other people leave their dogs or children the respondents speculated that people were planning to leave their dog and/or child in the car for only a short amount of time, that they were planning to do something quick. One of the respondents mentioned that some people have a more relaxed view on leaving their dogs in a car rather then their children.

Time

The majority of the respondents mentioned that they would have hurried if they had left their child and/or dog alone in a car. The time that was seen as reasonable when leaving them in a car was the time it usually takes to go and buy a parking ticket or withdrawing money from a cash dispenser, any longer time than that was consider as too long. One of the respondents even mentioned that if the action they were planning to perform would take too much time compared to what they think is reasonable, they were prepared to interrupt it and instead do it another time. The time it would take to go and do some grocery shopping was seen as too long and hence was something two respondents mentioned they would never do with their children left in the car.

> Yes, make sure to hurry with what you were doing and also make sure that it doesn't take much time.
>
> IP 4

Task analysis

To investigate the tasks performed when leaving the dog or child in the car a scenario was presented where the interviewee is arriving at a store, making some errands.

> I must point out that if we talk about that it is not hot, that it is safe then I would park my car and lower the windows a bit.
>
> IP 4

Since all of the respondents were aware of the risks with heat and cars, they would not consider leaving their dog or child in the car if it was hot weather. During somewhat hot circumstances when they actually would leave the dog or child there were some differences in the tasks that would be performed.

All of the respondents would lower the windows of the car when leaving the dog or child. One dog owner stated that they would provide the dog with water and making sure that the dog was not fastened in the harness anymore. Giving water to the dog was something that a veterinarian also stated is common, and one of the two parents interviewed would make sure that the children in the car had access to water, but not food due to the suffocation risk. The other dog owner was not sure if they would leave the dog with or without the harness fastened. The parents however were sure that they would leave the children with seat belts on, since there is a risk that a child would manage to exit the car or to suffocate on some small item otherwise.

> If the person before me in the queue would have taken too much time then I would probably have left the thing I was about to buy and leave. 5-10 minutes would have been okay.
>
> IP 3

The respondents would also hurry the errand that they were making, some even stated that if they felt that it took too long time (approximately more than 5-10 minutes) they would simply drop the articles and leave without finishing the errand. One veterinarian that occationally leave their dog stated that they return to the car on regular basis to make sure that the dog is fine when making errands. This was also something that one of the parents stated was the case when they left their child in the car while moving things between the car and house, returning to the car within seconds.

One of the parents stated that they would make sure to park the car in a place where people are able to see it, so that they could react if something happened to the child while the parents were away. For a flowchart of the task procedure summarised according to the interview results, see figure 4.2.

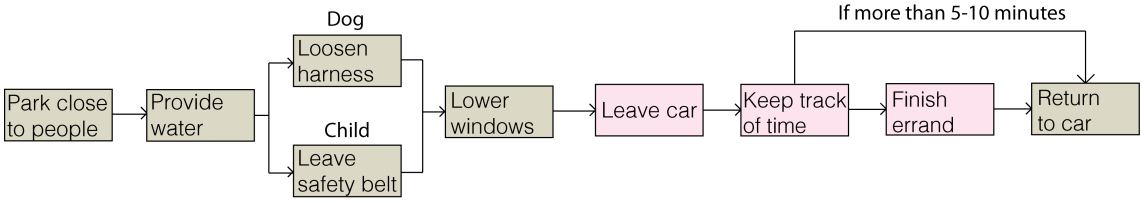


Figure 4.2: Task procedure of leaving dog or child in car

4.3.3 Risks and safety

The respondents themselves were quite aware of the risks related to leaving dogs or children in hot car. They however guessed that other people are not fully aware of how hot a car can actually get.

Risk awareness

Most probably, one interviewee speculated, people do not leave their dogs or children during hot days when they are aware that they will be away for long periods

of time, the issue is probably that people do not realise how fast a car can get hot.

> Yes absolutely, it is only during situations that I know it won't get hot in the car.
>
> IP 4

The respondents interviewed use their own feeling of how hot the weather is, and generally are precautious and not leaving a dog or child if they were unsure about the heat. One respondent stated that they used themselves as a reference, if they felt that it was shorts and t-shirt weather, they would not leave the dog in the car at all. Both parents and dog owners generally try to estimate the potential heat that will occur in the car, and where the shade will be during the day.

One parent stated that when their children will be about six years old they would feel comfortable leaving it alone in the car, since it would be able to open the door by itself. Another parent, who had three kids stated that they would wait until the oldest were at least ten years old, in order to be able to use a mobile phone to call the parents, and take care of their younger siblings.

Heat related safety for dog and child

> Of course, lower a window. Maybe try to have some kind of curtain or a jacket in order to prevent the direct sun rays.
>
> IP 2

Regarding the heat related safety, the respondents answered that they would definitely lower the windows before leaving it in order to get air into the car. The time of the year when they would perform this precaution was however varying. Some stated that they would not have done it in a weather condition when it was not sunny and mostly cold and rainy, however when it was really hot and sunny this was an action that was obvious. One parent stated that they would have unbuttoned the jacket of the child in order to get it more comfortable and prevent a high body temperature. The same parent also stated that another possible action would be to put up a blanket in front of the window near the seated child, this in order to prevent the sun rays from reaching the child.

General safety for dog and child

> Yeah that's a question about whether lowering the windows fully, then I wouldn't have my cute dog anymore.
>
> IP 4

Dogs that are pure breed and expensive might be theft-prone. One of the dog owners stated that they would not consider lowering the windows too much, since the dog could get stolen or could manage to escape the car by itself. This is a trade-off mentioned by a veterinarian, you have to lower the windows to the extent that theft might become an issue in order to get a sufficient cooling of the car.

One of the parents were concerned of the safety and would rather have their child staying inside of the car than managing to exit the car and get out in the parking lot where the child could get hurt. Both of the parents were concerned of the child managing to reach something in the car and suffocate or get hurt by anything hazardous if not fastened with a belt when left in a car. Also, the issue of leaving the car close to people were considered a trade-off, where it is beneficial if there are people close to the car who can act if the child left inside is suffering but on the other hand increasing the risk of a passer by in some way interacting with or scaring the children, or attempting some kind of harassment.

> So no, I would like him to be secured and placed in his seat, so that he can't get hold on something dangerous.
>
> IP 2

Car safety

Compared to the safety of the child or dog left inside the car the actual car was not something the interviewees considered important regarding safety aspects. The dog or child is most important and it would be worth the risk of lowering the windows and possibly having the car stolen compared to the risk of having the dog or child suffering from hyperthermia.

> Mm, no I wouldn't have thought about that in this case. I would prioritise my children.
>
> IP 1

Rules and information

> No not really. There is some sort of a consensus among parents that you don't do it, you have usually spoken about it in groups for mothers and there it is clear that you don't do it.
>
> IP 2

The answers among the respondents to the question on whether or not they have received any information about what happens when you leave a child and/or a dog in a car were varying. One respondent stated that they had seen an information poster when they visited their veterinary about how hot a car gets and how fast it heats up in the summer and also during the winter. Another respondent mentioned that they did not remember whether they had mentioned it when they were taking a course for new dog owners or not. Furthermore the social media, daily newspaper and the news were stated to be sources where they had seen information about dogs in cars. A parent said that they had not gotten any straight forward information about infants in cars but that there were a non-official consensus among parents that they usually do not leave their children in cars alone. In general parents are provided with a lot of information, but nothing or little related to hot cars.

> I know that you can't keep your dog there, but I don't have an idea for how long you can have it in the car.
>
> IP 4

There was one respondent that stated that they knew that it was illegal to store a dog in a car but they mentioned that they did not know for how long it was regarded to be okay to keep it in the car. The same respondent mentioned that they had no clue about if they had got any information about rules regarding dogs in cars.

4.3.4 Rescuing a dog or child with heatstroke

> Yes, if it seemed like the child or the dog looked affected and not feeling well then I would do it. I don't know if it is okay to break the window in order to save a dog according to the laws but I would do it.
>
> IP 4

If noticing a dog or a child left in a car the respondents all stated that they would at first try to see if the dog or child was affected by the heat. If so was the case some respondents were eager to break the window of the car, while other would try to contact the owner or parent for a longer period of time before calling the police and after that taking action. It could be embarrassing to break someones window if not completely necessary, therefore some would call the police to get permission to break it. One dog owner stated that they would call the police to turn in the rescued dog, while putting a sign on the car stating that they rescued the dog and that it can be found at the police station.

The parents both stated that if they saw that the child was screaming there would be no immediate danger, since the child can breathe and is awake. In that case the priority would be to get hold of the parents. If the child was silent it would be hard to tell if it was asleep or unconscious, and in that case both parents stated that they would check for breathing, and if no breathing could be seen they would act immediately.

> Give it water if I had some. Otherwise I would have waited for the owner to show up, but at this moment I have probably already called the police.
>
> IP 3

After finding some tool in the car or a stone and breaking the window the respondents would act a bit differently. One parent stated that they would perform cardiac resuscitation while calling for help from people in the surrounding, and call SOS Alarm. They would try to give the child something to drink and cool it. One dog owner stated that they would give a rescued dog water and wait for the owners, and call the police. The other dog owner stated that they would give the dog something to drink and using a wet towel to cool the dog. Another parent stated that they would look around and try to see if the parents to the child were near and if not they would have called the police.

Deciding to break into car

None of the respondents were completely sure about when it was a good idea to break the windows of a hot car with a dog or child left within. Regarding dogs one respondent stated that if it seems stressed it at least is not really ill yet, and the respondent would try to look for signs of if the dog had previously been stressed but now are not able to move anymore, or if it was panting heavily. The other dog owner stated that they would try to knock on the window and if the dog did not react to any outside stimuli it could be time to break in. Another sign stated was drooling in an unnatural way, panting and foam at the mouth. This respondent however felt unsure and would want to call someone (for example the police) to get advice on whether to break the window or not.

One of the parents stated that if the child appears asleep but seems to have no pulse or not breathing, appearing unconscious it would be a good idea to break the window. They would consider breaking the window if the child was red and screaming as well. The other parent also stated that if the child is red, then you have to do something immediately.

4.3.5 Attitudes towards products

When asked about products the answer was either that they did not know about any products that existed that would prevent a dangerous situation or that they were aware of that there was some kind of blanket that could reflect the incoming sun rays, preventing the car from getting hot. Another product that was mentioned was a child safety seat which had a canopy on top of it, also in order to prevent sun rays from reaching the child in this case.

> Yes exactly, they are supposed to remove 80% of the sun rays. I don't know how good they actually are, you can either way just use it in half of the car so I don't know how well it actually works.
>
> IP 4

Alarm that prevents you from forgetting dog or child in car

> You mean like an alarm? No that would not happen. I would not forget him just like that.
>
> IP 3

There were little to no interest among the respondents regarding an alarm that would prevent you from forgetting the dog or child in car. All of the respondents were aware of them having their dog or children in the car, and perceived the risk of forgetting it as small. Leaving the dog or child was perceived as something that would be on purpose.

One respondent expressed concerns that you would probably forget to use the product (if it was not fully automatic) if you were the type of person who would forget your dog.

> No because I don't think I have that problem but I think that it would be a good thing to have as a standard thing when you buy a child safety seat or something else.
>
> IP 2

The parents were more positive than the dog owners, and thought that it could not hurt to have an extra safety product, despite them not feeling a need for it. One suggested some kind of indicator when you turn off the ignition similar to the one that reminds you to use the seat belt.

Alarm that alerts if the temperature gets too hot

> Yes that would be damn good. An alarm that doesn't sound before it is too hot, more like "now it have started to get too hot".
>
> IP 4

The respondents had a very positive attitude against a product that would alarm when it got too hot in the car. They mentioned that it would be a relieve for them because they would not have to stress when doing their errands. Furthermore one of the respondents stated that it would be good with an alarm system that had a camera, making it possible for the user to see their child and/or dog in the car. Another respondent thought this type of product would be optimal for those that tend to forget their child and/or dog in the car without thinking about it, hindering a dangerous situation from occurring. A paediatrician that was interviewed stated that this type of product would be something that they would not recommend to their patients. However they thought that this type of product was more reasonable for dogs than children, they think that the parents should definitely not leave their children alone in a car.

A veterinary thought that an application for their mobile phone would be good, in order to help them see the temperature in their car. One of the parents also mentioned that if this type of product would be promoted in a right way, especially first time parents would definitely buy it since they are more anxiety ridden than parents that have several children.

> I would never recommend that type of alarm since that action states that you accept that parents leave their children alone in a car. With dogs I feel that it is more reasonable but I think that you should have your children with you.
>
> Paediatrician

4.4 Questionnaire

The questionnaire gave data from Swedish participants, complementing the international data found in the literature. In this section the most interesting parts of

the results are presented. In total 110 dog owners started the questionnaire and 83 competed it. For the questionnaire about children there were 50 parents that started the questionnaire and 34 completed it.

4.4.1 Dog owners

When the literature found in the literature study focused on actual cases of hyperthermia the questionnaire aimed at investigating the regular behaviours of dog owners. The questionnaire mostly had responses by people up to the age of 39, not reaching that many elderly dog owners (see appendix I, figure A.1). Also it can be noted that most participants were women (90%), and a few men (7%) and with 3% defining themselves as neither man nor woman. The mean value for dogs owned among the respondents is 1,54 dogs. A majority, 65% of the respondents drive a combi car, 12% drive a sedan and 16% do not drive a car at all.

Among the respondents it is common to leave the dog in the car on purpose, but not as common to forget the dog. Also, almost every respondent has seen another person leave the dog in the car (see appendix I, figure A.2). Only 8% state that they leave a short-nosed dog in the car, but 74% state that they have seen both short-nosed and non short-nosed dogs left by someone else in the car. The time the respondents leave the dog varies, and can be seen in figure 4.3.

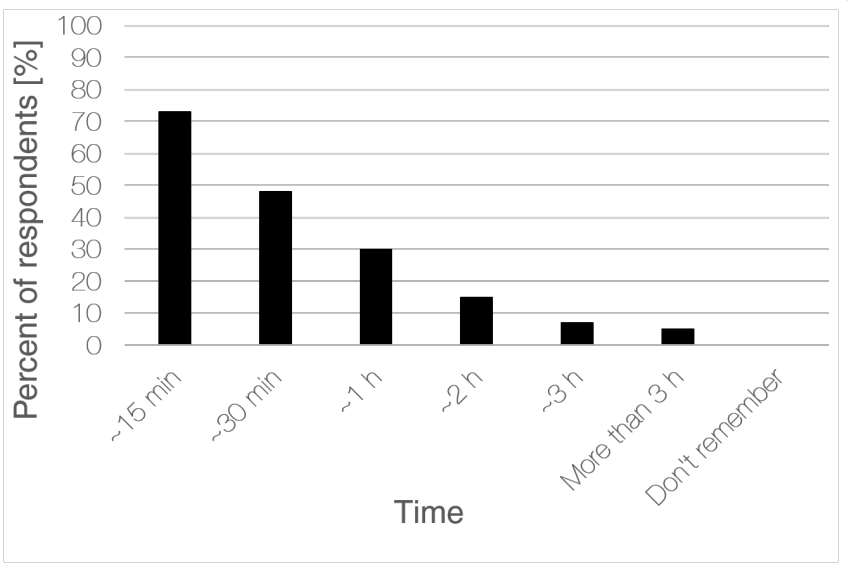


Figure 4.3: Time being left in the car - dogs

There are some variations in during which seasons the respondents leave their dogs in the car, slightly fewer do it during the summer months. However, the respondents have noticed other people's dogs left in car almost as frequently during all seasons (see appendix I, figure A.3).

When it comes to placement in the car there is a variation between the most common alternatives, placing the dog in a cage, belted in a harness or loose (see appendix

I, figure A.4). In the figure both the placements of the respondents own dogs, and the placements of dogs left by other people are listed. Among the responses recorded as other, all dogs are placed in the trunk of the car, with or without a fence.

The respondents state that they are aware of the risks related to the problem. 97% state that they are aware of how hot a car can get during a summer day, and 2% state that they are aware to some extent. When it comes to the risk of suffering from hyperthermia among dogs left in cars 98% state that they are aware, while 1% state that they are aware to some extent. Also, 95% have heard or read about any case where dogs have suffered from hyperthermia due to being left in a hot car. In relation to this the different precautions taken can be seen in appendix (see appendix I, figure A.5). As stated by the veterinarians interviewed, lowering the windows do not have any effect on cooling the dog, and if you put the car in the shade there is a risk that the sun will move. There seems to be a variation to what precautions are taken, and when. Among the other options listed, four people state that they use the climate control in the car to cool the car, three people leave water for the dog and six respondents use sun protection on the windows of the car. Leaving the car in a garage is an option that three mentioned. Other precautions include opening a roof window of the car, having a wet towel for cooling and giving the dog a frozen bone to chew on and a cooling mat. In comparison, figure 4.4 describes what precautions the respondents have seen other persons take when leaving their dogs in cars.

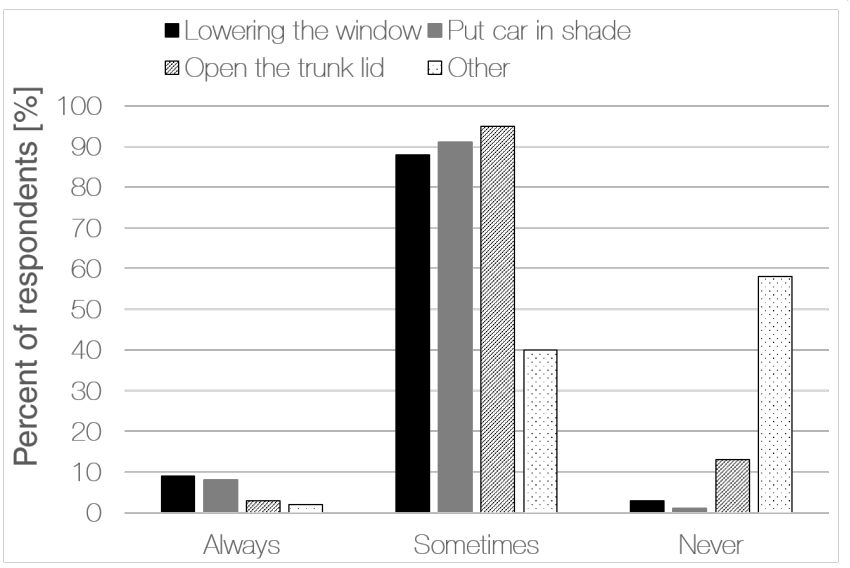


Figure 4.4: Precautions seen when noticing dogs left in car

It can be noted that only six persons stated that they use something that could be interpreted as a product designed for the purpose of preventing hyperthermia among dogs left in cars. To investigate the interest for a future product the respondents were asked if they would consider buying an external product or a car with an integrated system to prevent hyperthermia. The results can be seen in figure 4.5.

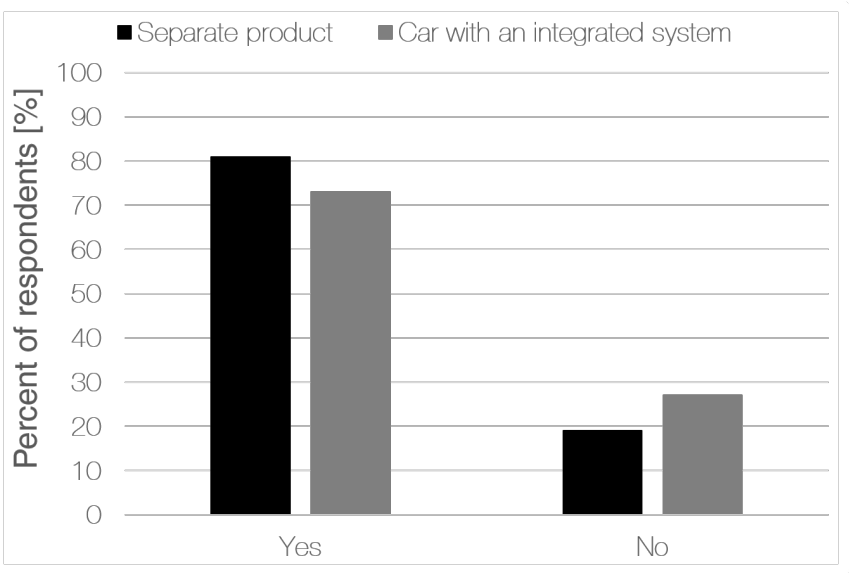


Figure 4.5: Interest in future product - dogs

Among the comments left in the final question the participants discuss their thoughts about leaving dogs in the car. People comment that *"I never leave the dog when it is very hot or cold outside."* and *"If it is above 15-20 degrees I never leave the dog for longer than 15 minutes."*. Also one person commented that *"I adjust the precautions depending on season."*. There are people who keep the dogs in their cars during dog trainings or competitions. During these situations people help out with keeping an eye on each others dogs, taking multiple precautions as well. These dogs are left in the car for multiple hours but the owner regularly tends to the dog during this time. *The Swedish Board of Agriculture* regulates the time that the dog can be left in a car. The maximal time allowed is three hours, and the dog has to have access to water at least every sixth hour (Swedish Board of Agriculture, 2015).

4.4.2 Parents

The questionnaire aimed towards parents and caregivers did not have as many answers as the one aimed towards dog owners. Also the responses from parents or other caregivers did not reach many elderly. See figure 4.6 for the age distribution among responses. As with the dog questionnaire a majority was women, 94%. On average the respondents have 1,73 children.

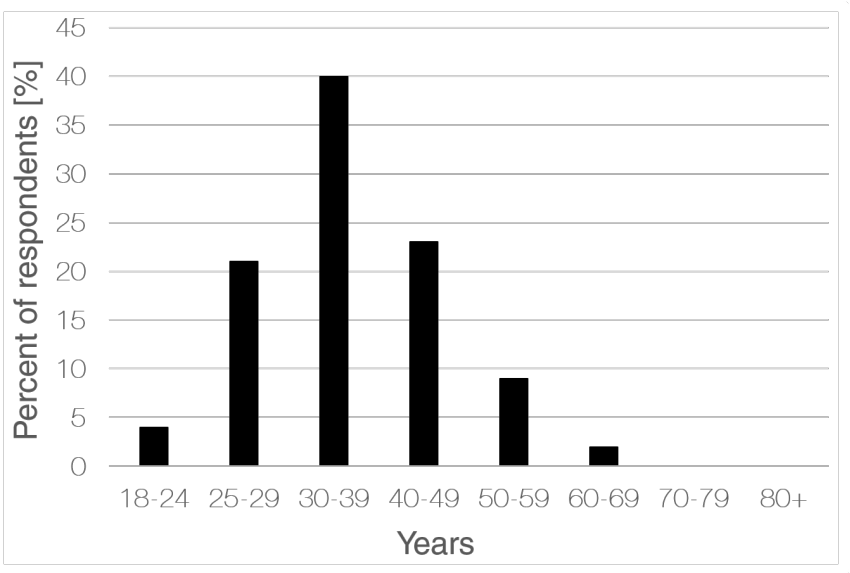


Figure 4.6: Age of parents and caregivers

Also for the parents/caregivers a majority, 78% drives a combi car. In addition 18% drives a sedan and 9% does not drive a car at all. No parent has forgotten their child in a car, but 44% leave their child(ren) occasionally in the car (see appendix I, figure A.6). A majority has seen children left in cars by others occasionally or frequently. According to the questionnaire it is more common to leave the child in the car as the children get older. This is also the case when the respondents have noted other persons leaving children in cars (see appendix I, figure A.7).

It can be noted that there is not a large difference between how long the children are left alone in the car for children of different ages (see appendix, figure A.8). As the paediatrician that was interviewed stated: children of about 5-6 years of age are probably able to get out of the car by themselves if it gets uncomfortably hot.

In a previous study by Booth et al., 2010, on cases of hyperthermia resulting in death the children left in cars were left between 0,25 to 16 hours, see section 2.9. Among the questionnaire answers it was noted that many of the respondents state that they usually leave or have left their children in a car for approximately 15 minutes. The time the children are left according to the responses lies within the time range that in the study by Booth et al., 2010 has lead to fatal consequences. The behaviour stated in the questionnaire could therefore be a risk for the child during dangerous, hot, weather circumstances. It is however not confirmed whether the children left according to the questionnaire were left during these circumstances, but should that be the case there could be a risk of hyperthermia for the child.

In the questionnaire it was investigated if the age of the child affects during what seasons the child is left. In general people seem less likely to leave their children in the car during summer and winter, but due to the few amount of answers no clear conclusion can be drawn if people with younger children are more cautions not to leave them during summer, see figure 4.7.

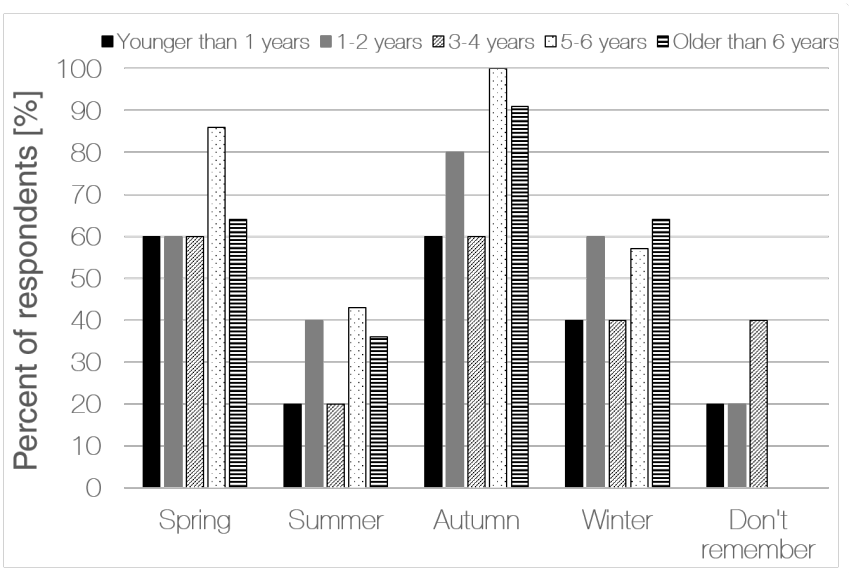


Figure 4.7: Time of year and age of children being left in cars

Among the responses who have seen another child left in a car, the same distribution with less children in the summer and winter can be noted (see appendix I, figure A.9).

When being left in a car the children are placed in different ways, see figure 4.8. A baby safety seat refers to the kind of seat you put small babies in, the child safety seat is a seat for young children, and child car seat and booster seats are seats that only elevate the child a bit higher in the seat.

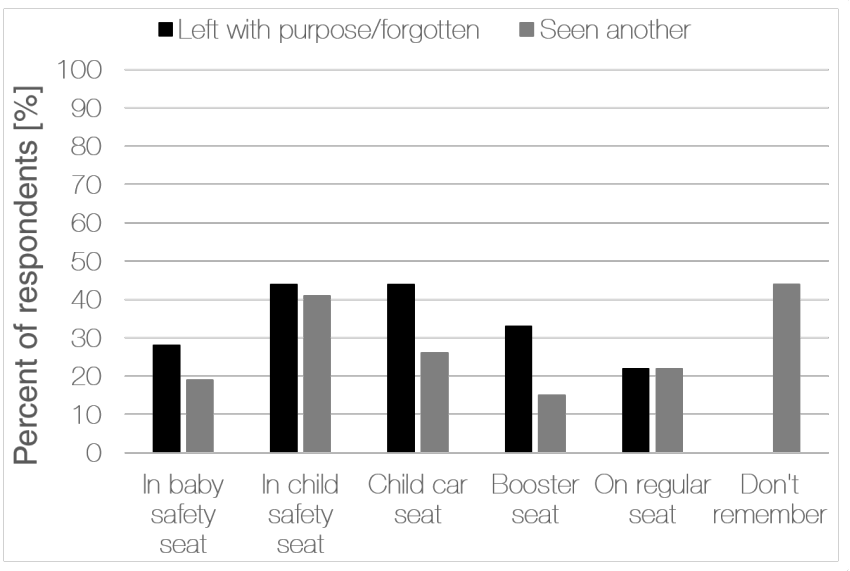


Figure 4.8: Placement of children left in cars

The child placed in the car may or may not be fastened with a seat belt. According to the questionnaire most children that are left in cars seem to be left fastened with seat belts and not with the belt unbuckled (see appendix I, figure A.10). It can be noted that the use of precautions and safety measures are similar among dog owners and parents. The use of baby monitors are not more frequent among parents according to the responses in the questionnaire, which could be the case. To get representative data for the actual use of products, another study would have to be conducted but the data gives indications that the use of safety measures are similar for parents and dog owners. For the frequency of different precautions, see figure 4.9.

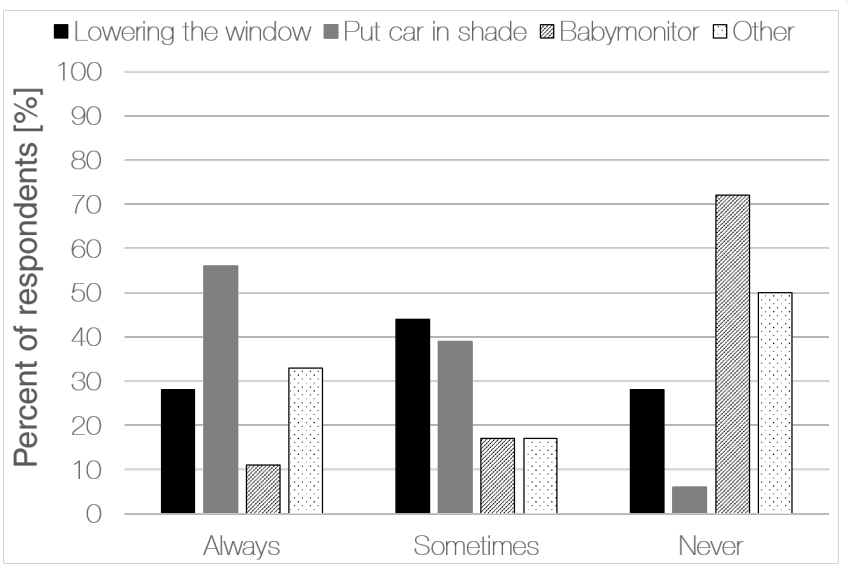


Figure 4.9: Precautions taken when leaving children in cars

In comparison figure 4.10 describes what precautions the respondents have seen other persons take when leaving their children in cars. Other people seem to not use precautions as often, but the case could also be that a passer-by are not able to notice every precaution taken except for the obvious ones.

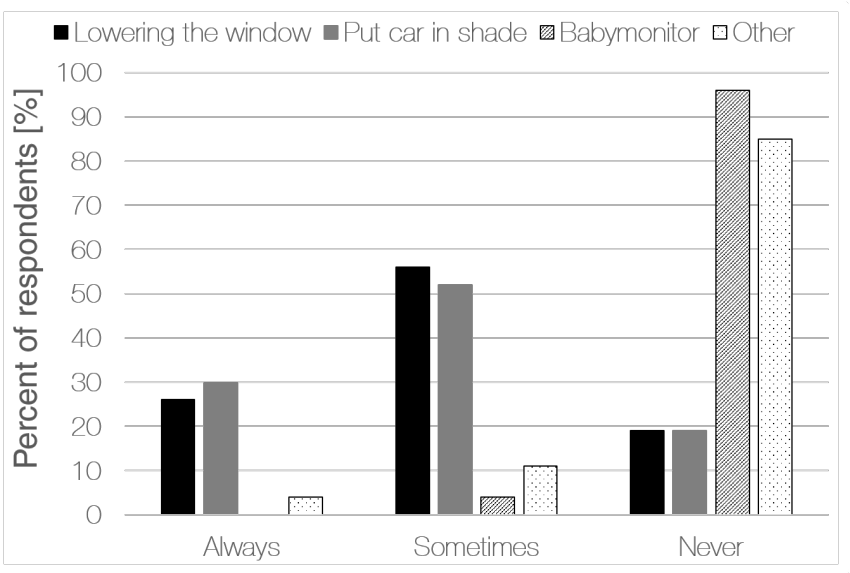


Figure 4.10: Precautions seen when noticing children left in car

Fewer parents/caregivers of children stated that they were aware of the risks with cars getting hot during summer. 90% state that they are aware, and 10% state that they are aware to some extent. On the other hand 97% state that they are aware of the risks of leaving their child in a hot car, and 3% state that they are aware to some extent. Also, 95% have heard about any case where a child has suffered from hyperthermia after being left in a car during hot weather. Despite this the parents responding to the survey are not as eager as the dog owners to buy products to solve the problem (see appendix I, figure A.11). A reason for this could be that children to a lesser extent are left in cars on purpose, and that the caregivers do not see a need for a product, while dog owners more frequently leave their dogs in the car on purpose. When comparing the interest in a separate or an integrated product the dog owners had a larger interest in a separate product, while the parents wanted an integrated one.

The answers to the written final questions are critical towards leaving children in cars alone. One states that *"It is not normal to forget a child in the car. [...] Children who are not able to get out of the car by themselves should not be left alone"*. Another one state that *"If the child cannot lower the window or open the door by themselves if they feel uncomfortable they should not be left in the car at all"*. One comment states that the respondent would like a built in safety system, but would not pay for it, and would not adjust the behaviour and trust the system completely. One issue addressed is also that *"You cannot make laws against stupidity. Those who would need such a product do not buy it"*.

4.4.3 Risk awareness and safety products

In the final open question both parents and dog owners addressed a concern that a product solving the problem might be problematic if it induced a false feeling of security. If the product is trusted to a very high extent parents or dog owners might

put their children and dogs in more dangerous situation if they are depending very much on the system.

Another reflection made in the questionnaire by the participants was that the people buying the product might not be the people that who would leave or forget the child or dog in the car, resulting in a dangerous situation. People who actively buy a product are probably already aware of the risks with cars getting hot, and therefore not the source of a dangerous situation anyway.

As the respondents in the questionnaires comment, this is something that is important to consider when designing a new safety product. Before introducing a new safety system for children and dogs left in cars to the market some kind of risk perception analysis would be necessary to conduct.

4.5 User needs

The user needs are a result from interviews with dog owners, parents, the questionnaires and to some extent medical interviews. The needs are weighted with relative importance according to a survey answered by 30 dog owners and parents in total. In the survey 79% of the participants were dog owners and 45% were parents. The age of the participants varied between 18-59 years. 90% of the people that answered the survey were women, 9% were men and 1% were ones that defined themselves as neither man nor woman. Combi cars and sedan cars was what the majority of the participants stated that they used. For full results of the questionnaire regarding the importance of the different needs (see appendix O).

The importance of the needs were based on the results from the survey, but interpreted by the project group to give a more accurate number. See the user needs list including the importance below.

The product:

Prevents children and dogs from suffering from heatstroke/hyperthermia in cars
- Is trustable [5]
- Does not induce a false feeling of security [5]
- Does not encourage leaving [4]

Works in different use situations
- Considers children and dogs both intentionally left and forgotten [5]
- Functions without user interaction necessary [3]
- Ensures the general safety of a child or dog left inside [4]

Is usable for different passengers left in the car
- Considers dogs of all possible sizes [4]
- Considers children of ages 0-6 years [4]

Is usable for dogs placed in different ways
- Is usable for dogs placed in cage, buckled in a harness or loose in the car [4]
- Is usable for dogs placed in the front seat and in the back seat [4]

Is usable for children placed in different ways
- Is usable for children placed in car safety seats, with or without seat belts, and children free in the car [4]
- Is usable for children placed in car safety seats turned backwards and forwards [4]
- Is usable for children placed in the front seat and in the back seat [4]

4.6 Personas

Two personas representing people driving *Volvo XC90* that are potential users of the developed systems were created based on the experiences about users from the pre-study. These are used and kept in mind during the development of the system further on.

4.6.1 Maria, 38

https://www.flickr.com/photos/macrj/5614050826/

• Specialist physician within the field of surgery
• Lives in a house in Askim, south of Gothenburg
• Married to David, 40. IT Manager
• Has three children, two girls 6 and 2 years old, one boy 6 months old

During the weeks Maria drives their *Volvo XC90* to work, usually taking the children to preschool on the way. At the moment she is on paternity leave with the youngest son, but soon it is David's turn to go on leave. The family mostly uses the *Volvo XC90* for grocery shopping, since it has room for the whole family and the groceries. Occasionally David has to work late nights, forcing Maria to take the children in the car to the store alone. Sometimes she leaves them inside the car alone for doing a quick errand, since three kids can be hard to manage in the store alone. David's parents live in Trelleborg, and Maria and David takes the car for longer trips when they visit them. They enjoy that the car has room for the whole family and luggage for long trips. Maria also loves the built in features, making life with a family easier.

4.6.2 Svante, 56

https://www.flickr.com/photos/capturetheuncapturable/8275093820/

- Entrepreneur with own company
- Lives in a house in Toltorpsdalen, Gothenburg
- Married to Margareta, 57 years old land surveyor
- Has one child, Carl 19 years old who lives and studies in Stockholm
- Country house on Hönö island outside of Gothenburg

Svante and Margareta run a dachshund kennel, owning three grown up dogs but currently no puppies. When not busy with the company, Svante enjoys going out hunting with some of the dogs trained for hunting using their *Volvo XC90* to transport the dogs and equipment. Together the couple also loves taking the dogs out to the forest for mushroom picking. The car is commonly used for grocery shopping, but occasionally Svante goes on semi-long hunting trips. Occasionally during the hunting trips some of the dogs get to stay in the car for periods of time. The couple has a country house on Hönö in the archipelago where they stay on weekends and on their longer vacations, using the *Volvo XC90* to transport themselves, the dogs and various kind of goods needed for the house. They also go on longer trips to visit their son Carl in Stockholm. Svante looks forward to retirement when he will spend more time on Hönö with the dogs and his wife.

4.7 Expression Association Web

The Expression Association Web includes words reflecting the desired experience of the developed system, with the foundation in the vision and goals of the *Volvo XC90* and the desires of the users, see figure 4.11.

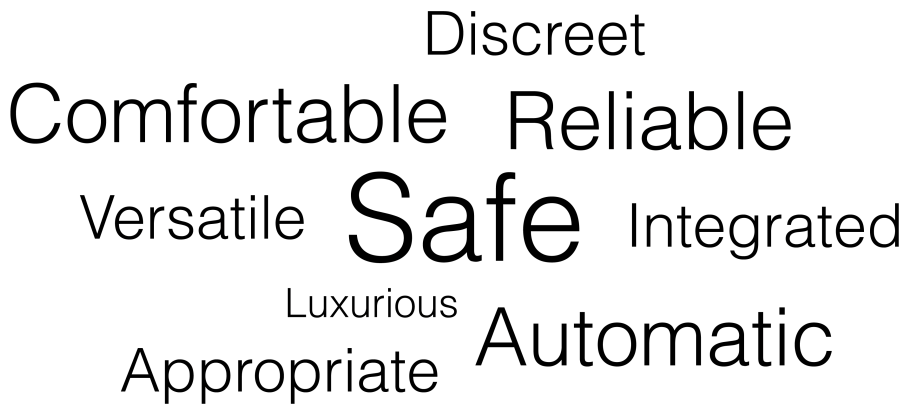


Figure 4.11: Expression Association Web

4.8 Inspiration Board

The images in the Inspiration Bord serve as an inspiration in the development work. The Rolex watch symbolises a premium and luxurious design, the umbrellas represents a simple protection against sun rays. In addition the pocket knife represents the multiple functionality the system needs to have in order to solve a complex problem. The lifebuoy represents a well known symbol of safety, and safety is the core of the system. In addition the lifebuoy is easily recognisable with well known functionality. The car with the x-ray print represents the medical nature of the project, and the fact that the system needs to be able to detect passengers and heat inside of the car, see figure 4.12.

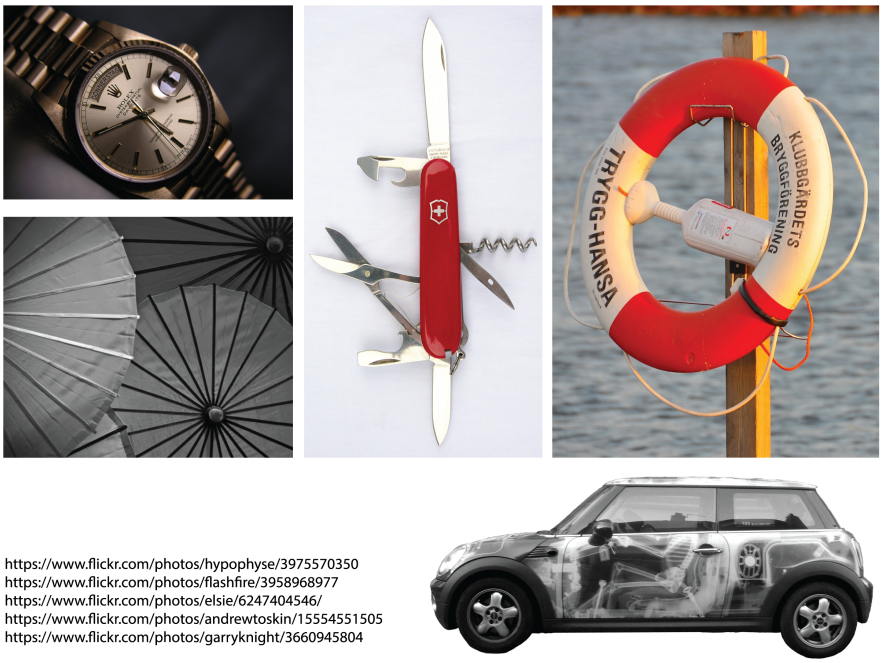


Figure 4.12: Inspiration Board

4.9 Summary of pre-study

In this section the results from the interviews with the users and professionals, presented in chapter 2, the resuts from the questionnaire and benchmark are summarised and analysed.

4.9.1 Products and attitudes

- There are existing products and patents.
- The veterinarians and paediatrician do not know about any products.
- The interviewed parents and dog owners do only know about some kind of screen to protect the car from sun but no other products.
- According to the questionnaire people do not use products that aims at solving the problem to a large extent at all.
- A product that prevents you from forgetting a dog or child in the car was seen as unnecessary by the interviewed parents and dog owners.
- A product that alarms when the car gets too hot was considered as more interesting.
- Dog owners responding to the questionnaire had a larger interest for products solving the problem compared to parents, this is probably due to the fact that dogs are more frequently left in cars on purpose.
- There is a risk that a new safety product introduced on the market affects the behaviour of the user in unwanted ways, inviting them to take risks to a larger extent.
- Some people may have trouble trusting a product, while other may trust it too much. It is important that a product design truly reflects the safety functions included.

4.9.2 Risk, information and awareness

- Veterinarians and paediatricians try to inform people about the risks related to cars and hyperthermia.
- It is unsure if the information reaches enough dog owners and parents.
- Almost all respondents to the questionnaire state that they are aware of the risks, not only to some extent.
- People are aware of the risks with cars getting hot, but they do not have an accurate feeling of how fast it gets hot and how hot it can get.
- Outside temperature in combination with the sun is considered as dangerous by dog owners and parents, but in reality sun rays can heat the car when the outside temperature is not that high.

4.9.3 Knowing how to act and symptoms

- The symptoms of hyperthermia are not easy to notice among dogs, you can see the panting but internally almost anything can collapse.

- Children do not pant or have clear visual symptoms, and it can be hard to know if a child is asleep or suffering from hyperthermia.
- The breed, size of dog, fur et cetera do not make a lot of difference when it comes to heat.
- The size of car matters, small cars heat up quicker, but in the end all cars will get hot.
- Cooling of a dog suffering from heat stroke is important, immediately cooling before driving to the clinic will make the difference between life and death in severe cases.
- As with dogs immediately cooling is important among children, but children should not be cooled as rapidly.
- People state that they would break a window if they had to rescue a dog or child, but first they would try to reach the owner/parent or call the police.
- There were no consensus among during what situations it would be appropriate to break a window or what symptoms to look for. It was regarded as complicated because the symptoms are hard to notice.
- People do not realise how important immediate cooling is for survival.

4.9.4 Situations, circumstances and precautions

- People usually leave dogs or children in cars when making quick errands, the risk is however that you forget about or misjudge the time they take.
- Children are probably most often left with seat belts on, due to the risk of suffocating on any item left in the car.
- Heat is not the only concern, general safety such as having the dog stolen or strangers interacting with children are of concern.
- The safety of the car is not considered to a large extent compared to the safety of the dog or child left inside.
- Lowering the window was a common precaution that was thought to be effective. In reality it does make little to no difference.
- Dog owners are more relaxed when it comes to leaving dogs in cars compared to parents leaving children.
- Parents probably most often forget the children while dog owners leave dogs on purpose.
- Many people state that they see others leave dogs or children in cars, but in relation fewer admit to doing it themselves.
- According to the questionnaire dogs are left between 15-60 minutes while children are only left for about 15 minutes.
- It is more common to leave older children alone in the car.

5

Subsystem concept design

In this chapter the subsystem concept design phase is described. The phase as part of the whole project process can be seen in figure 5.1. The subsystem concept design phase started with a brainstorming session were different brainstorming methods were used in order to generate many different concepts. While performing this brainstorming session the general needs and user needs were considered. The session resulted in 83 subsystem concepts. These concepts were categorised into nine different categories in a span between proactive and reactive actions. Continuously a scatter plot was made with the coordinate system defined by proactive to reactive on the x-axis and from human to car on the y-axis.

In order to eliminate the concepts that was not considered relevant and feasible for the project a yes/no screening was conducted. After this screening there were 55 concepts left. Furthermore another screening was performed, this time with an evaluation on whether the concepts were trustworthy and would be possible to develop further or not. All the concepts that would not work were eliminated. After this second screening there were 41 concepts left. In order to be able to combine the different subsystem concepts into full system concepts the existing concepts were sorted out into six different categories. Each of the categories consists of different solution types, as for instance using a sensor or calling for help. In the end of this phase, requirements for a full system were generated in order to be used when full systems are evaluated.

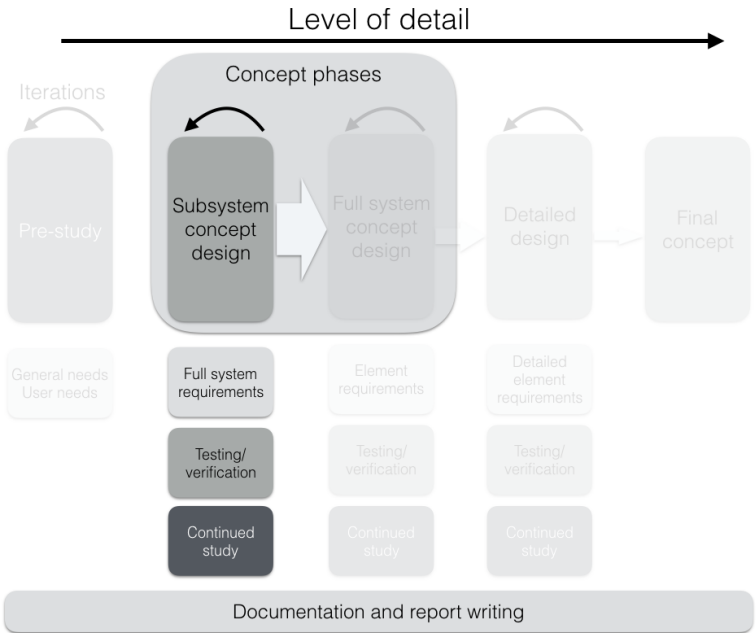


Figure 5.1: Process phase subsystem concept design

5.1 Categorisation according to course of events

Images of every developed subsystem concept can be found in the appendix (see appendix J). Before the screenings the solution space was initially studied through a categorisation. These categories were related to the course of events, with proactive solutions on one end, and reactive on the other end. The result is that the whole span from very reactive concepts to very proactive ones were covered, with a bit more emphasis on cooling concepts, see figure 5.2.

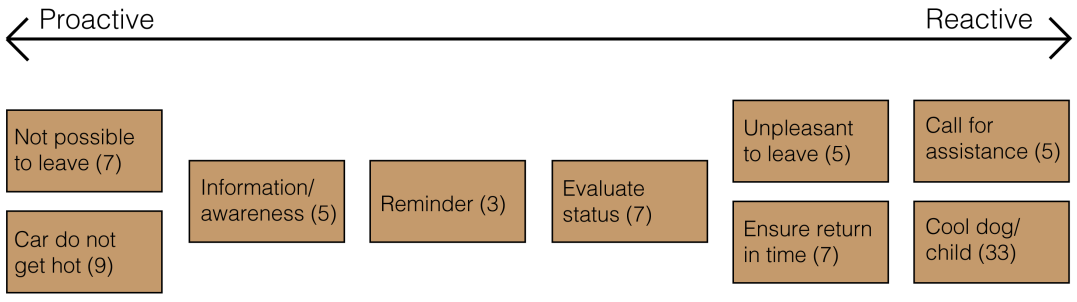


Figure 5.2: Categorisation according to course of events

5.2 Scatter plot analysis

The produced concepts are not only distributed on the proactive-reactive scale according to the course of events. They also differ in how automated they are. To further analyse the spread among the concepts a scatter plot was used, with the proactive-reactive scale on one axis, and a human-car scale on the other. A concept that is at the car end of the scale fulfils it purpose with no need for human interference. A concept on the human side of the scale does so with no interference of the car. The distribution among the concepts is concentrated to certain areas, as can be seen in figure 5.3 with an emphasis on the more automated concepts using the car to fulfil their purpose. There are more concepts on the reactive side of the scale as well. The scatter plot with the reference numbers to each concept can be found in appendix (see appendix K).

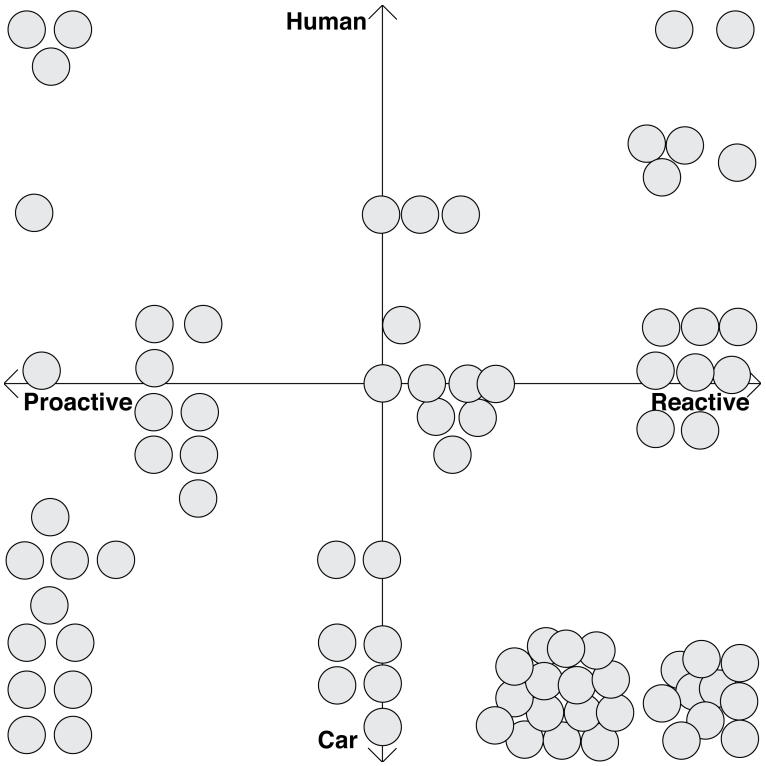


Figure 5.3: Scatter plot of concepts

After the two different screenings approximately half of the concepts were discarded, see figure 5.4. It can be noted that all concepts that were only relying on human efforts were removed, since it had been noted in the pre-study that human behaviour is one of the main causes of the problem in the first place. It is also evident that the most reactive concepts that relies only on the car to fulfil the purpose were removed in the screening. If you have a fully automated system it is better to use proactive means before a child or dog is severely injured, there is no point with waiting to cool it until it is almost too late when you could have started with cooling earlier to ensure a stable body temperature.

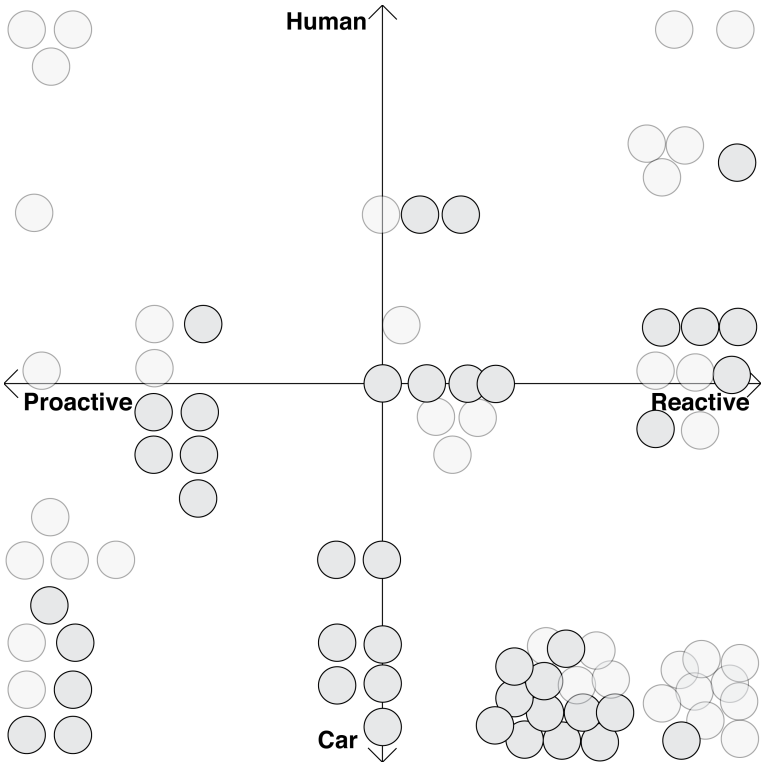


Figure 5.4: Scatter plot of concepts after screening

5.3 Feasible concepts

After both screenings the remaining concepts were sorted into different categories in order to allow for combinations into full systems. The categories are presented below along with brief descriptions of the concepts included. The full range of concepts is presented in appendix (see appendix J).

5.3.1 Emergency cooling

Since most of the concepts related to very reactive measures were removed in the screening only a few remained. These included some kind of storage for cold water in the car, a rescue kit and a voice guide automatically triggered by the car during an emergency situation.

5.3.2 Ensure cool environment inside of car

Most of the cooling concepts were a bit more proactive, aiming at keeping the environment inside of the car at a pleasant temperature. Among these concepts some included automatically opening doors, windows, the trunk et cetera. Others aimed at reflecting the sun rays with tinted windows, curtains or paint, and some used the air conditioner, a dehumidifier and other cooling measures such as using solar panels to power a cooling system. These are all supposed to be automatic and prevent the car from getting dangerously hot.

5.3.3 Not possible to leave dog or child

Since there is a need among the users to actually leave their dogs in the car not that many concepts aimed at preventing this. One concept however involves some kind of system to ensure that it is impossible to lock the car if anyone is left inside it, both to prevent the driver from forgetting a dog or child and in the cases when a dog or child is left on purpose it should be easier to rescue it.

5.3.4 Status report

Some concepts aimed at providing information to the parent or dog owner when they have left the car. Among these some are different kinds of weather prognosis to give a more accurate view on the heat situation, and different bracelets worn to monitor the pulse and heat inside of the car providing real-time haptic information. One concept also gives a warning on the dashboard similar to other warnings that someone is still in the car, to prevent parents and dog owners from forgetting their child or dog.

5.3.5 Sensor

In order to get the different cooling systems to work properly sensors of different kinds are needed to monitor the status inside of the car. These include temperature sensors of different kinds, audio interpretations, cameras and weight sensors. These concepts are supposed to be used in combination with other concepts to provide information on the situation and when to take different actions.

5.3.6 Call for assistance

If a dangerous situation occurs and the child or dog needs to get out of the car would occur there are concepts aiming at calling for assistance. There are concepts where the car makes noises or flashes the lights, and different kind of concepts where any passer-by is contacted and where other cars are alerted.

5.4 Full system requirements

According to the different categories of subsystem concepts presented in section 5.3 full system requirements were listed. In addition the user needs in section 4.5 and general needs in section 4.2 were interpreted and rephrased according to the technical solution space generated. The full system requirements are weighted according to relative importance. The requirements that concern the users are weighted according to interpretations of the results of user ratings in a survey (see appendix O) and the rest are weighted by the project group alone.

Relation to the car

- Is sold together with the car [4]
- Is an integrated solution [3]
- Does not interfere with the design of the car [4]
- Utilises existing technology inside of the car as much as possible [2]
- External components are resistant to humidity and rain [4]

Functionality

- Considers dogs of all possible sizes [4]
- Considers children of ages 0-6 years [4]
- Ensures that dog body temperature does not reach 41 degrees [5]
- Ensures that child body temperature does not reach 40 degrees [5]
- All critical functions are automatic [3]
- Ensures a stable temperature inside of the car [3]
- Is able to detect a child or dog left in the car [5]
- Is able to detect a child or dog regardless of placement [4]
- Is able to alert if the child or dog is in heat related danger [4]
- Only activates energy consuming features if a child or dog is left alone inside [2]
- Does not require the engine to supply system with electricity [4]
- Only activates any kind of alarm if a child or dog is actually left alone inside [4]
- Does not grant unauthorised people access to the car [4]
- Does not interfere with the comfort of the child or dog [5]
- Is sustainable [2]

Usage

- Does not require the user to interact with additional products (except from mobile phone/car keys) [3]
- Does not encourage the user to leave a dog or child unattended [4]
- Does not require any learning of the user [2]
- Does not require extensive change in behaviour among users [4]
- Gives the user access to information on the current situation inside of the car [3]
- System components that depend on human action are not critical to ensure the safety of the dog or child in the car [3]
- All information provided to the user regarding the situation inside of the car is correct [5]

6

Full system concept design

In the full system concept design phase full systems are created out of the subsystems. The phase as part of the whole project process can be seen in figure 6.1. The full system concept phase stared with an adapted Morphological Matrix were nine full system concepts were developed by combining different subsystem concepts. The developed full system concepts were evaluated through a Pugh matrix. The criteria used in the matrix were based on the two needs lists, see section 4.2 and 4.5. In the Pugh matrix, three of the full system concepts were eliminated since they got low rating in the matrix and were not feasible. After the initial screening only six full system concepts were left. Another concept got eliminated since it required too much effort from the user, hence five concepts were left. Parts of some of the eliminated concepts were kept in order to integrate and reuse them in the other remaining concepts after further evaluation. Moreover another concept got eliminated since it had too many uncertainties, lowering the number of concepts left to four. These four full system concepts were evaluated by users using a Semantic differential, see section 3.3.5, and based on the user input and the technical aspects the four systems were evaluated with a Kesselring matrix - resulting in two concepts scoring highest. These two concepts in combination make up the final concept that was developed.

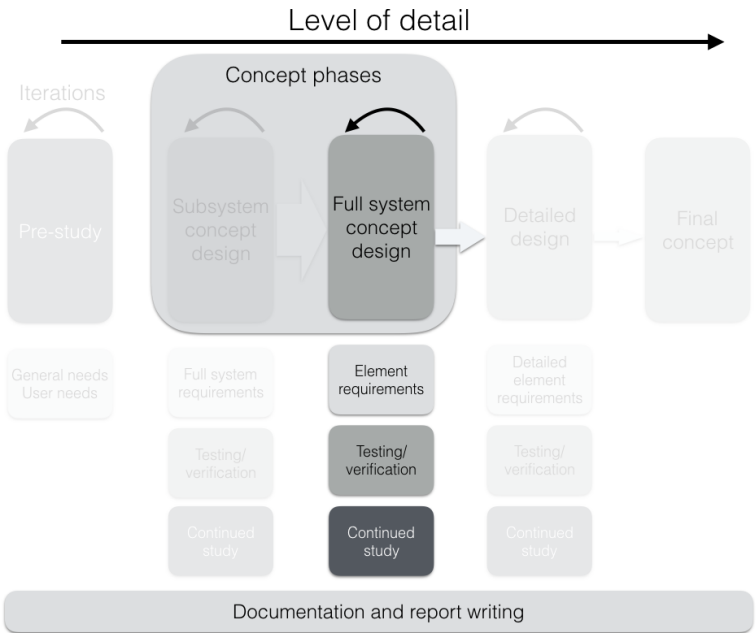


Figure 6.1: Process phase full system concept design

6.1 Development of full system concepts

The full system concepts were created through combining different subsystem concepts that were previously developed and categorised into six categories (see appendix L were the different categories with the included subsystem concepts are presented). The subsystems were combined in a systematic way by analysing which of the concepts that would possibly work in combination with each other. Thus, nine different full system concepts were achieved, the Car seat concept, Pulse-o-meter, Hot bracelet, Human rescue, Solcar cell prognosis, Shadow monitor, Audio opener, Don't leave me and AC cooling, see table 6.1.

Table 6.1: Concepts generated by an adapted Morphological Matrix

Full system concept name	Subsystem categories					
	Not possible to leave	Sensor	Maintain cool temperature	Status report	Call for help	Emergency cooling
Car seat concept	**5** Car not possible to lock if somebody is left inside	**83** Thermometer **35** Pressure sensor	**26** Car seat cooler		**10** Blink at heat **11** Alarm at heat	
Pulse-o-meter		**57** Measure pulse	**31** Darkening windows **27** Rejecting paint	**55** Pulse bracelet	**30** Alert smartphones close	
Hot bracelet		**38** Infrared camera	**44** AC cooling	**76** Heat bracelet	**1** Alert owner/ parent	
Human rescue		**38** Infrared camera **83** Thermometer			**1** Alert owner/ parent **11** Alarm at heat **18** Volvo app access to car	**22** Rescue kit **25** Voice guide **21** Cold water storage
Solcar cell prognosis		**83** Thermometer **3** Camera in car	**56** Sun energy to cooling	**82** Measure sun rays, prognosis	**74** GPS measure time and distance alert owner/ parent	
Shadow monitor		**35** Pressure sensor **53** Shadow camera	**41** Lower the windows	**49** Weather prognosis in car	**1** Alert owner/ parent	
Audio opener		**19** Scream monitor **32** Panting monitor **83** Thermometer	**61** Dehumidifiers **43** Open the trunk lid **40** Automatic door opening **34** Door with net protection		**1** Alert owner/ parent	
Don't leave me	**5** Car not possible to lock if somebody is left inside	**35** Pressure sensor		**80** Warning dashboard	**79** Flash if anyone left in car	
AC cooling		**38** Infrared camera	**44** AC cooling		**1** Alert owner/ parent	

After evaluating the nine full system concepts in a Pugh Matrix (see appendix M) five of the concepts were eliminated because they were considered difficult to realise or because of that there were too many uncertainties with the concepts. This resulted in four remaining concept, the AC cooling, Hot bracelet, Human rescue and Solcar cell prognosis.

6.2 Remaining concepts after evaluation

In this section information about the four final remaining full system concepts can be found. The concepts are not specified in detail, but an overview of the general functionality is presented. In addition the results of the four user interviews with Semantic differential results are summarised for each system. Further information about the Semantic differential interviews can be found in section 3.3.5.

6.2.1 AC cooling

Inside of the car one or many infrared cameras are installed, able to detect humans and animals inside of the car, as well as the temperature of all surfaces, see figure 6.2. There is also a thermometer to measure the air temperature. If the temperature of the dog or child or air starts to rise the car automatically starts to adjust the temperature using the air conditioner (AC). Notifications are sent to the caregiver or dog owner through the *Volvo On Call* application if the car gets hot, for example if the AC is not cooling the car sufficiently or if it has a malfunction.

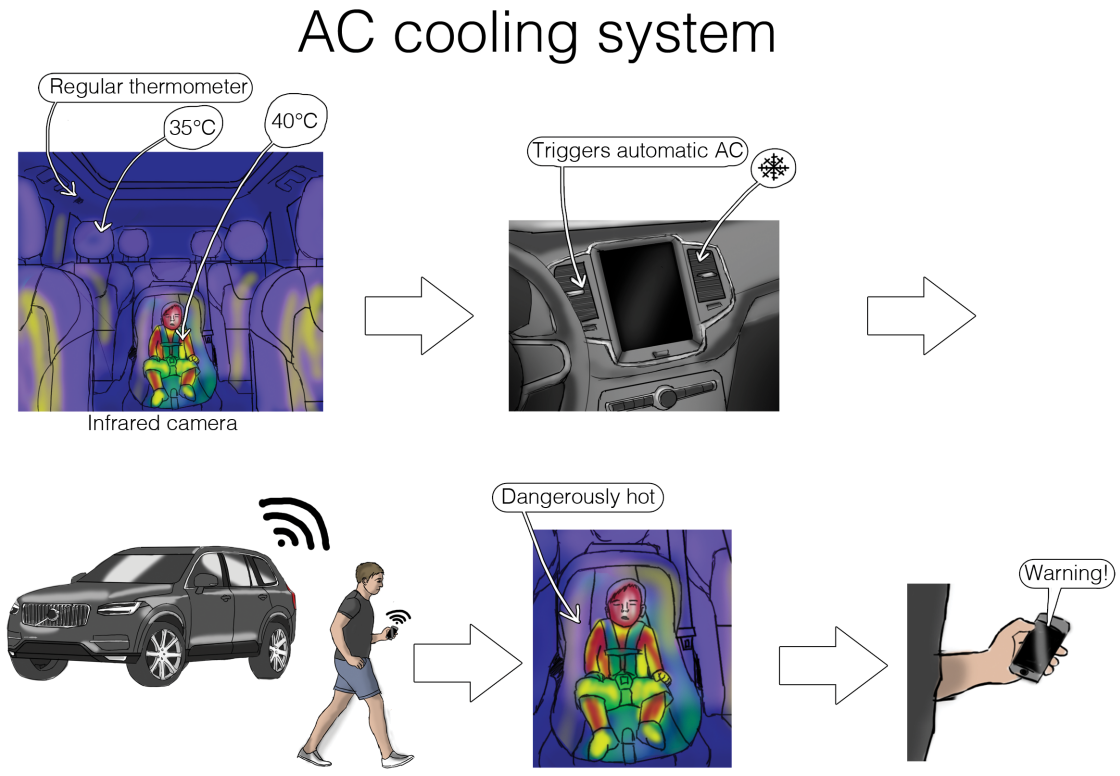


Figure 6.2: The AC cooling system concept

The AC cooling system was considered as the favourite among the four parents and dog owners interviewed. IP6 stressed the fact that it probably would be hard to trust it in the beginning but that you would learn to trust it when you had used it a couple of times. IP8 was more sceptical and had a general distrust of mobile applications, since mobile phones can run out of power. The AC cooling system was generally considered as automatic, and the users did not feel that they had to do much at all. A feature that the users wanted was the ability to check the status of the system in their phone, not only getting a warning when it is too hot inside of the car. IP5 also mentioned a concern that the system did not have a final way of solving the situation, should the AC not work and the owner not return to the car, suggesting lowering the windows. See figure 6.3 for a summary of the Semantic differential results for the system.

Figure 6.3: Semantic differential - AC cooling

6.2.2 Hot bracelet

Inside of the car one or many infrared cameras are installed, able to detect humans and animals inside of the car, as well as the temperature of all surfaces, see figure 6.4. There is also a thermometer to measure the air temperature. If the temperature of the dog or child or air starts to rise the car automatically starts to adjust the temperature automatically triggering the AC. Inside of the car there is some kind of storage containing a bracelet to be worn by the caregiver or dog owner. The bracelet gives haptic information of the temperature inside of the car by getting hotter as temperature rises, reminding the user of the situation. This also ensures that the caregiver or dog owner knows that the AC has started, the bracelet will not get hot. If. for some reason, the AC does not work at all or sufficiently the bracelet gets hot and when the car starts to get potentially dangerous the caregiver or dog owner get

a notification through their mobile phone. The notification utilises the *Volvo On Call* application. If the bracelet is not worn the car will still initiate the AC cooling and give a notification to the mobile phone if it is time to return.

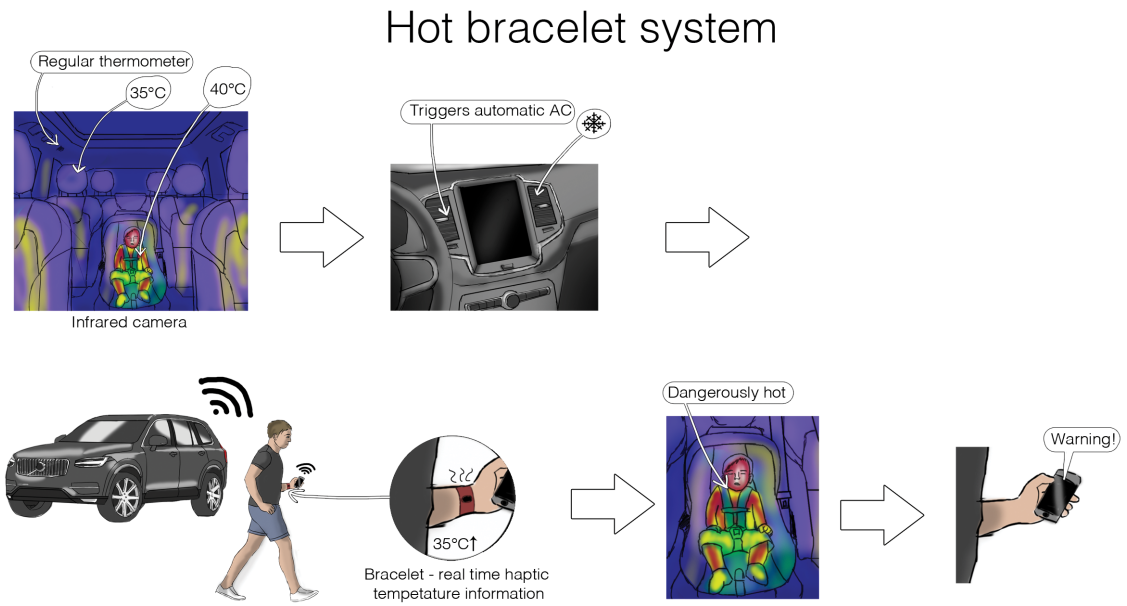


Figure 6.4: The hot bracelet system concept

The Hot bracelet system had mixed reviews among users. Generally the bracelet was considered as being more manual compared to the AC cooling system. IP5 appreciated the extra feedback from the bracelet, and IP8 liked the fact that it was not the mobile phone receiving updates only, since a phone can run out of battery power. IP6 and IP7 however thought that the bracelet would be unnecessary, IP6 would prefer the phone to receive updates instead of the bracelet. The system was less appreciated than the AC cooling system, and the perceived value of the bracelet did not motivate its existence. See figure 6.5 for a summary of the Semantic differential results for the system.

Figure 6.5: Semantic differential - Hot bracelet

6.2.3 Human rescue

Inside of the car one or many infrared cameras are installed, see figure 6.6. These are able to detect a human or animal left in the car. In addition a thermometer is installed to measure air temperature. If the temperature gets dangerously hot the car alerts the dog owner or caregiver through the *Volvo On Call* application, and if the caregiver or dog owner does not return to the car after a specified amount of time the car alerts other people close-by by sounding an alarm, and simultaneously unlocks the doors. The passer-bys can get the dog or child out of the hot car. When someone (the car owner or a passer-by) enters the car a voice guide gives instructions on how to act to rescue the child or dog. In the car a rescue kit is available for use in this task, possibly cold water is found somewhere in the car. The car starts the voice guide when the door is opened and it notices a human inside that can listen to the instructions.

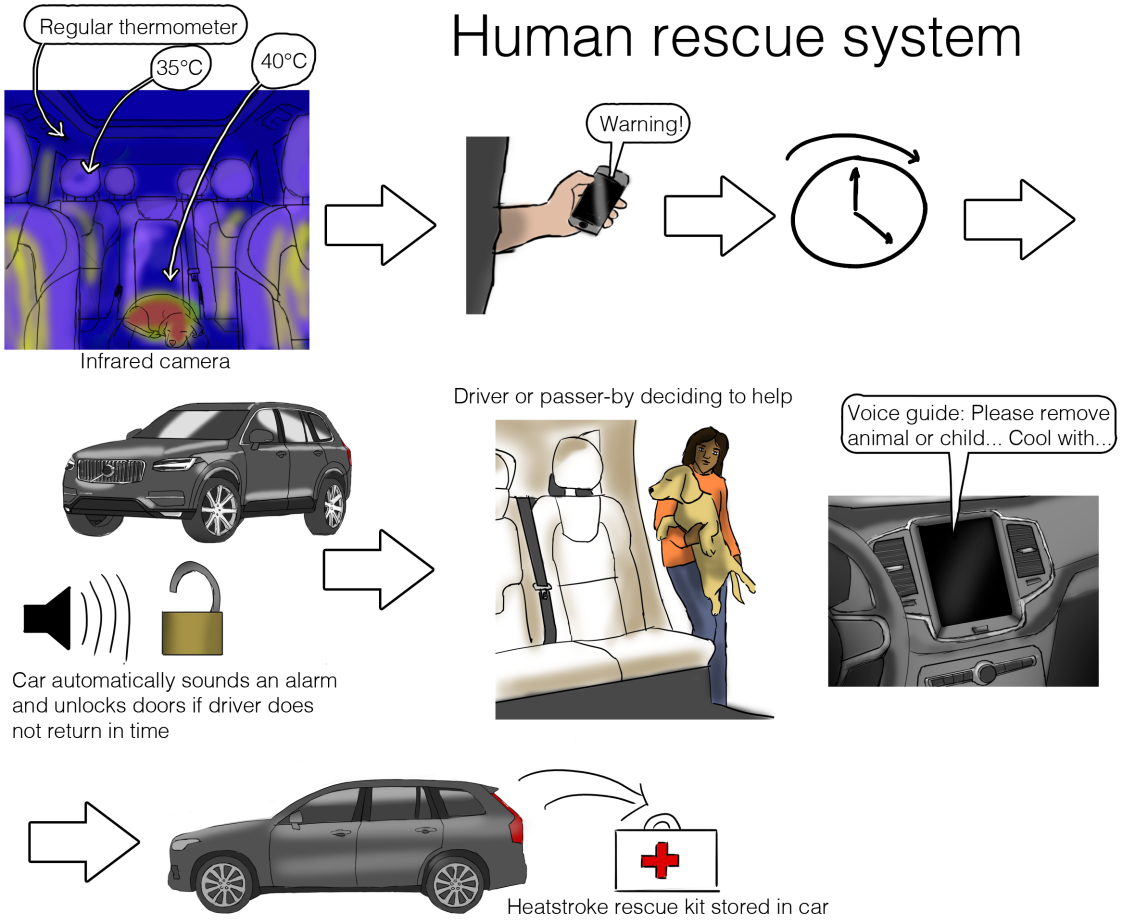


Figure 6.6: The human rescue system concept

Among the systems the users all agreed that the Human rescue system would not work. All users were concerned that people would not manage to rescue the dog or child, and that people would not react to a car sounding an alarm. The system was not trustable to the users, since they would not rely on other people. IP6 and IP7 mentioned the risk of the car or the child or dog inside getting stolen if the car unlocked the doors. Another risk with the concept mentioned by IP8 was that it could cause stress among the dogs or children left inside of the car, due to the alarm. The users also agreed on that probably they or the passer-by rescuing the dog or child inside of the car would not listen to the voice guide, and the system was perceived as complicated due to many people being involved. See figure 6.7 for a summary of the Semantic differential results for the system.

Figure 6.7: Semantic differential - Human rescue

6.2.4 Solcar cell prognosis

The car is equipped with a solar cell panel somewhere, see figure 6.8. This panel is used for projecting the temperature inside of the car by measuring the sun rays. The caregiver or dog owner gets a prognosis of how long they can safely leave a child or dog inside of the car before they exit the car. Inside of the car there is a thermometer and cameras able to detect a child or dog left inside and to measure air temperature. If a child or car is left in the car and the temperature rises the AC starts, powered by the solar energy collected. The prognosis, along with the current temperature in the car is used to alert the caregiver or dog owner if the car is in the risk of becoming dangerously hot despite the AC trying to cool the vehicle (due to inefficiency or malfunction). A GPS is used to measure the distance between the car and the caregiver or dog owner, and gives an alert depending on distance to allow them to return in time.

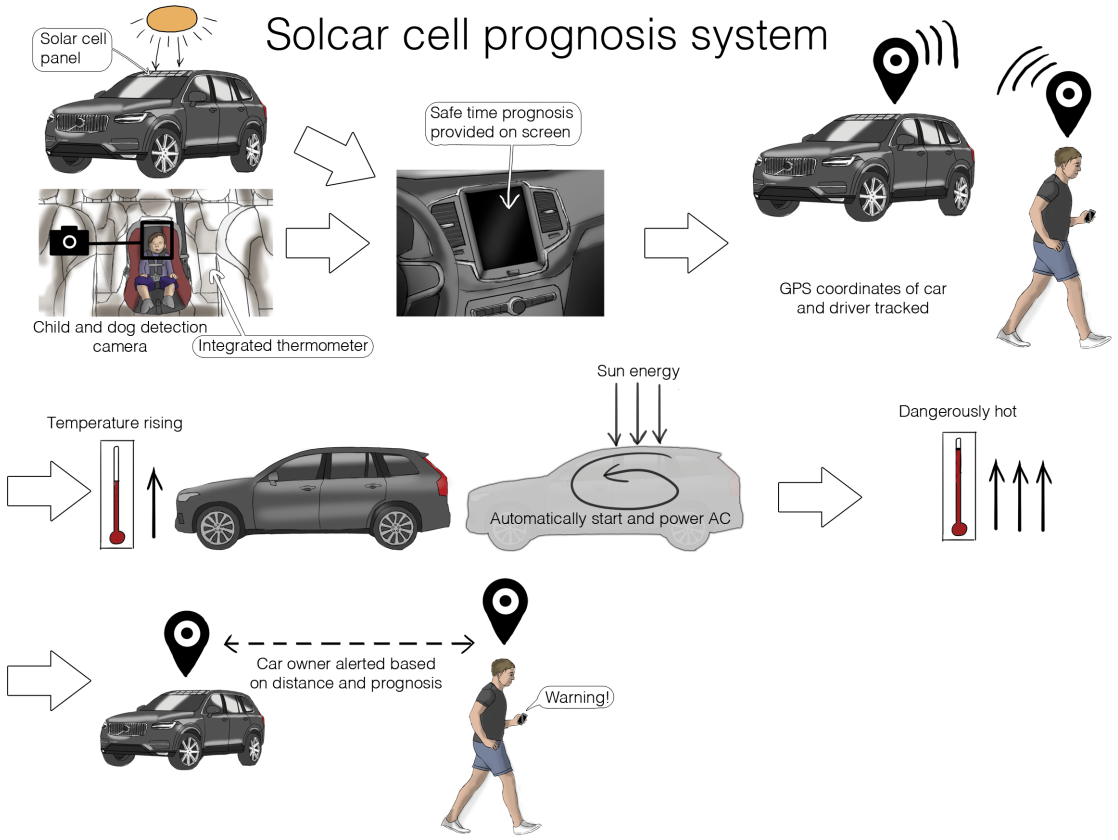


Figure 6.8: The solcar cell prognosis system concept

The prognosis provided by the system had mixed reviews. IP6 thought that it would be useful for a system without the additional features. IP6 however thought that it was confusing to get a prognosis of how hot the car would get without cooling, when in reality the car would be cooled. IP5 and IP7 would not trust the face recognition system as much as infrared cameras, and IP6 stated that they would feel that a system that has many backup features assumes that something would go wrong, making them think that the basic features do not work properly.

The GPS functionality was generally appreciated among the users, IP8 would appreciate it since they leave one of their dogs in the car during training sessions in the forest and walk quite long distances. The solar panels added an extra safety dimension, not worrying for the power supplies of the systems. The safety of the system would encourage the users a bit to leave their dog or children in the car. See figure 6.9 for a summary of the Semantic differential results for the system.

Figure 6.9: Semantic differential - Solcar cell prognosis

6.3 Final concept selection

The four full system concepts were also evaluated with the Kesselring method with a matrix. The criteria used are the full system requirements presented in section 5.4. When determining the score for each concept and criteria the technical aspects as well as the comments and thoughts from the Semantic differential user interviews were considered. The full results of the Kesselring method can be seen in table 6.2 and 6.3.

Table 6.2: Kesselring matrix

		Ideal		AC Cooling		Human Rescue		Hot Bracelet		Solcar Cell Prognosis	
	Importance	**Score**	**Total**	**Score**	**Total**	**Score**	**Total**	**Score**	**Total**	**Score**	**Total**
Relation to the car											
Is sold together with the car	4	5	20	5	20	5	20	4	16	5	20
Is an integrated solution	3	5	15	5	15	2	6	3	9	4	12
Does not interfere with the design of the car	4	5	20	4	16	3	12	3	12	4	16
Utilises existing technology inside of the car as much as possible	2	5	10	4	8	3	6	3	6	3	6
External components are resistant to humidity and rain	4	5	20	4	16	4	16	3	12	3	12
Functionality											
Considers dogs of all possible sizes	4	5	20	4	16	4	16	4	16	3	12
Considers children of ages 0-6 years	4	5	20	4	16	4	16	4	16	4	16
Ensures that dog body temperature do not reach 41 degrees	5	5	25	4	20	1	5	4	20	4	20
Ensures that child body temperature do not reach 40 degrees	5	5	25	4	20	1	5	4	20	4	20
All critical functions are automatic	3	5	15	5	15	1	3	5	15	5	15
Ensures a stable temperature inside of the car	3	5	15	3	9	1	3	3	9	4	12
Is able to detect a child or dog left in the car	5	5	25	4	20	4	20	4	20	3	15
Is able to detect a child or dog regardless of placement	4	5	20	4	16	4	16	4	16	3	12
Is able to alert if the child or dog is in heat related danger	4	5	20	4	16	4	16	5	20	5	20
Only activates energy consuming features if a child or dog is left alone inside	2	5	10	4	8	4	8	4	8	3	6
Does not require the engine to supply system with electricity	4	5	20	2	8	4	16	2	8	5	20
Only activates any kind of alarm if a child or dog is actually left alone inside	4	5	20	4	16	4	16	4	16	4	16
Does not grant unauthorised people access to the car	4	5	20	5	20	1	4	5	20	5	20
Does not interfere with the comfort of the child or dog	5	5	25	4	20	1	5	4	20	4	20
Is sustainable	2	5	10	3	6	4	8	3	6	4	8

Table 6.3: Continued Kesselring matrix

		Ideal		AC Cooling		Human Rescue		Hot Bracelet		Solcar Cell Prognosis	
	Importance	**Score**	**Total**	**Score**	**Total**	**Score**	**Total**	**Score**	**Total**	**Score**	**Total**
Usage											
Does not require the user to interact with additional products (except from mobile phone/car keys)	3	5	15	5	15	1	3	2	6	5	15
Does not encourage the user to leave a dog or child unattended	4	5	20	3	12	4	16	3	12	3	12
Does not require any learning of the user	2	5	10	5	10	1	2	3	6	4	8
Does not require extensive change in behaviour among users	4	5	20	4	16	1	4	3	12	4	16
Gives the user access to information on the current situation inside of the car	3	5	15	1	3	1	3	3	9	1	3
System components that depend on human action are not critical to ensure the safety of the dog or child in the car	3	5	15	4	12	1	3	4	12	4	12
All information provided to the user regarding the situation inside of the car is correct	5	5	25	3	15	3	15	2	10	4	20
T=sum T		495		384		263		352		384	
T/Tmax		1		0,775757576		0,531313131		0,711111111		0,775757576	
Ranking				**1**		**3**		**2**		**1**	

As a result, two concepts score equally good, the Solcar cell prognosis system and the AC cooling system at 78% of the maximal score. The Human rescue system only received 53% of the maximal score, and would require too much change in order to be useful, and the safety issues with the system were not popular among users. The Hot bracelet system scored 71%, and actually received a lower score compared to the similar AC cooling system despite adding extra features. Since adding more features and technology that do not add an equal amount of benefit for the users compared to the cost and effort, the Hot bracelet system was seemed as unnecessary complicate to keep developing. The aspect of giving continuous updates on the situation in the car was kept as an idea, only not through an additional product.

6.4 Combination of systems to final concept

The final concept consists of the earlier presented AC cooling system with add-ons from other systems and is called HeatSafe, see figure 6.10. Since both the AC cooling system and the Solcar cell prognosis system got the highest ranking in the Kesselring matrix and also since the interviewed persons found some parts in both of the systems to be appealing, the final concept is a combination of these. In order to be able to identify people in the car and to measure heat in the car infrared cameras will be used. A thermometer will be used to measure the temperature inside of the car and also to trigger the installed infrared cameras when it starts to get hot inside. A solar cell will be installed on the car complementing the existing battery of the car. It will power the automatically triggered AC and the installed infrared

cameras. A mobile application that will provide the user with real time updates from the condition inside of the car will also be added and a notification will be sent to the user when the AC is started through this application. Another feature that will be present in this system is that the car will be able to calculate how long time it will take for the user to return to the car based on the location of the user and alarm in time. This feature will be used when the AC does not cool the vehicle sufficiently.

Both the solar cells and the feature that will be able to keep track of the user and calculate the time it takes for it to go back were found to be positive features by the interviewed dog owners and parents. The interviewed persons found the system to be more relying with a solar cell installed since the battery would then have a backup power source. The GPS system that can keep track was also found to be convenient. The system felt more safe for the user knowing the car would keep track of you and the car at the same time. The addition with the real time update about the condition in the car was previously presented as a bracelet the user would wear. The interviewed persons considered getting real time updates from the car beneficial, however a bracelet that would reflect the temperature inside of the car to the user was not appreciated. They stated that it would be difficult to notice when it got hot and that it would be hard to know when to react and get back to the car in time, also that they would probably feel placebo heat when none were present. In this final system the real time update will be presented in the application instead making the user feel more confident with the information they get.

Some users tend to take precautions when leaving a dog or child inside of a car. These behaviours, including opening the trunk lid and lowering the windows in order to prevent high temperatures inside a car will still be possible to perform. The system will not start the AC or send notifications to the user if the temperature in the car does not get dangerously hot, but if the temperature rises despite these precautions the system will activate.

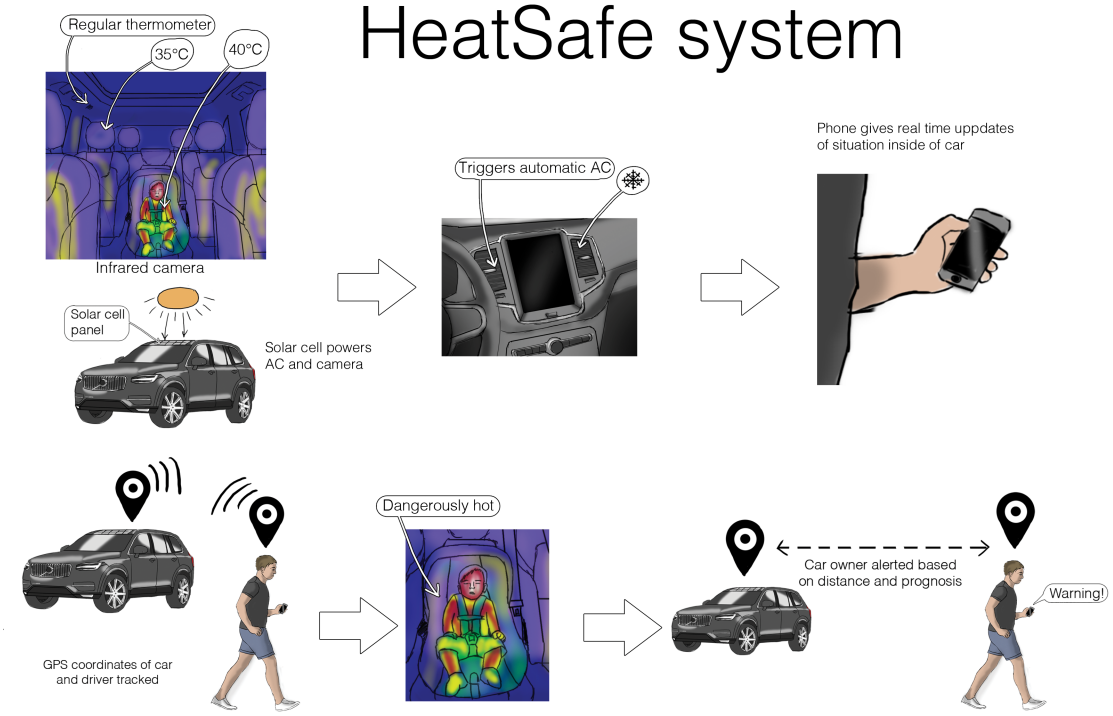


Figure 6.10: HeatSafe system

6.5 Element requirements

Below the requirements for the different elements included in the selected concept system are presented. The requirements are on a general level, and are further defined during the detailed design phase.

Infrared cameras

Placement

- Able to detect dog or child on seat
- Able to detect dog in cage with roof
- Able to detect dog on floor
- Able to detect child in backwards facing seat

Power preserving

- Able to take still pictures
- Silent

Sensitivity

- Sufficient temperature accuracy
- Large field of view

Thermometer

- Sufficient temperature accuracy

- Small
- Able to integrate in car

Solar cell

- Thickness as small as possible
- Able to adapt to car shape
- Possible to get see-through
- Sufficient effect

AC

- Connected to battery rather than engine
- Able to maintain comfortable temperature range

Mobile application

- Provide real time updates
- Give informative notifications
- Give warning notifications
- Be a part of *Volvo On Call*

GPS

- Measure distance between driver and car

Software

- Receive temperature information from thermometer
- Interpret temperature information
- Trigger infrared cameras
- Identify dog and child
- Trigger AC
- Send information to mobile application
- Calculate distance and time to return based on GPS
- Send warning to mobile application

7
Detailed design

In this chapter the process and results from verifying, testing and developing the different elements of the HeatSafe system are described. The detailed design as part of the whole project process can be seen in figure 7.1. The chapter presents the separate elements of the HeatSafe system, the climate system, solar panel, infrared cameras, mobile application and software necessary to control the system. For each element the feasibility is further evaluated if necessary and the remaining elements are developed and tested using different methods, both using real components and digital mock-ups. The economical feasibility of the HeatSafe is investigated and an FMEA on the whole system is presented. In the end of the chapter a requirements list with detailed element requirements is presented, a development of the more general element requirements presented in section 6.5. The final version of the system, designed according to the conclusions and results from the detailed design phase is described in chapter 8, final concept.

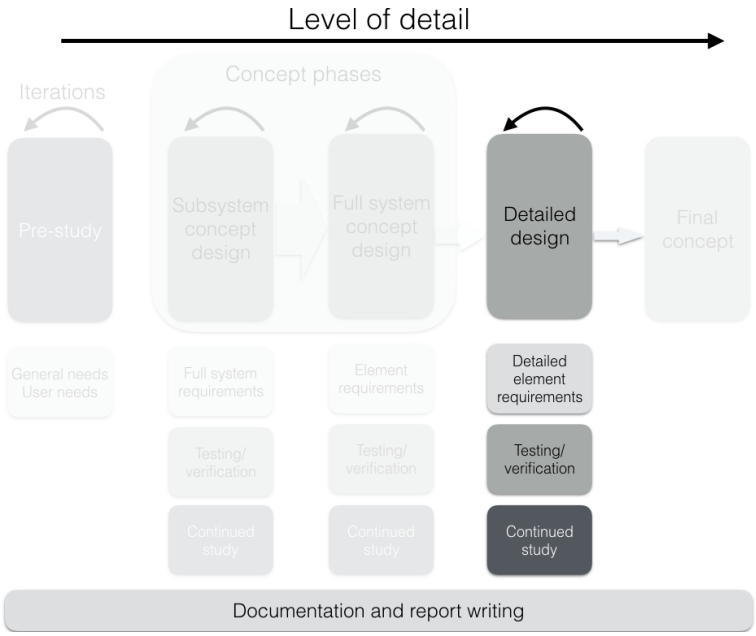


Figure 7.1: Process phase detailed design

7.1 Climate system

The HeatSafe concept utilises the climate system to cool the car. In order to investigate the feasibility of the concept the climate system was discussed with an expert in the field, and estimations on the required power were made based on calculations and secondary research.

The *Volvo XC90* comes with either an diesel or petrol engine, or an hybrid version with an electric and petrol engine (Volvo Cars, 2016c). As interpreted of information provided by Volvo Cars, the XC90 with the hybrid twin engine has the climate system powered by the hybrid battery instead of the regular version where the climate system is powered by the diesel or petrol engine (Volvo Cars, 2014).

Currently the *Volvo XC90* have a function that allows the user to trigger the climate system on demand in order to cool or heat up the temperature inside the car through using the mobile phone application *Volvo On Call*, see section 2.12.3. Hence the function in the HeatSafe system with automatically starting the climate system is not an addition to the current functions of the car.

Industrial doctoral student Filip Nielsen at the Building Services Engineering department (personal communication, 22 March 2016) described that in order to remove hot air inside of the car there are two options available through the climate system: cooling the air with the air conditioner (AC) or using the ventilation to exchange the hot air inside and the (supposedly) cooler air outside of the car. Due to the inefficiency with using only the ventilation, where the air close to the intake gets hot, using the AC to cool the air would be the only feasible option.

7.1.1 Power consumption

In order to compare the available power of the engine or hybrid battery of the XC90 with the required power of the AC calculations were made based on previous research made on the topic.

A study by Farrington and Rugh, 2000, found that an air conditioner generated a maximal load of 3 kW. In addition calculations made by Subiantoro, Ooi, and Stimming, 2014, estimated a required compressor power of between around 1500 to 2600 W to keep an indoor temperature of 20°C, and a power of between approximately 1400 to 2000 W to keep the temperature indoor at 26°C. Srinivasan and Phadke, 2006, showed in their test that to keep the air conditioner on in an SUV idling, generated a power consumption of approximately 2 kW.

As a conclusion the value of 2000 W was set as an approximation for the air conditioner load. The system does not require a comfortable temperature inside of the car, only an temperature that ensures no damage on dogs or children left inside.
The engine in the XC90, as previously mentioned in section 2.12 has a power of 140 kW, while the hybrid battery of the twin engine car has a power of 9,2 kWh. It can

therefore be concluded that there is sufficient power even in the less powerful hybrid battery to run the AC for a sufficient amount of time:

$$T = \frac{9,2\,kWh}{2\,kW} = 4,6\,hours \tag{7.1}$$

However, there might be issues with having the car automatically start the AC in the case with the diesel or petrol cars. In those cases starting the AC will result in emissions, while starting the AC in a hybrid car will not due to the hybrid battery being used.

7.2 Solar panel

The selected concept are supposed to utilise solar cell panels to power the AC instead of having the engine or hybrid battery supply the AC with power. In order to estimate if solar panels could provide enough power calculations were made based on typical data from Sweden, and the estimated data on required power to run the AC.

According to Sigurd and Stolt, 2016, a typical solar cell in Sweden generates up to 150 $\frac{W}{m^2}$. An estimation of the necessary solar cell surface area to power the air conditioner can be calculated:

$$A_{req} = \frac{2000\,W}{150\,\frac{W}{m^2}} = 13,33m^2 \tag{7.2}$$

The width and length of the *Volvo XC90* are 2008 and 4950 mm respectively (Volvo Cars, 2016c). There will be no possibility to achieve an area large enough for the required solar cell area on top of the *Volvo XC90*, which area can be roughly estimated:

$$A_{car} \approx 4,950m * 2,008m \approx 9,9396m^2 \tag{7.3}$$

Installing solar cells on the entire top area of the car would generate only 75% of the required energy:

$$W_{gen} = 150\frac{W}{m^2} * 9,9396m^2 = 1490,94W \tag{7.4}$$

$$W_{frac} = \frac{1490,94}{2000}W = 0,74547 \approx 75\% \tag{7.5}$$

Even having solar panels on the entire top surface of the car would not generate a sufficient amount of energy to power the AC. Therefore solar panels with the efficiency of today is not feasible for the concept, and does not fulfil the requirement of sufficient effect listed in section 6.5. Instead the AC will have to function the same way as today, with the hybrid battery or engine supplying it with power.

7.3 Infrared cameras

The only new hardware to be implemented in the *Volvo XC90* is, with the removed solar panels, the infrared cameras, due to the fact that solar panels are not feasible. The infrared cameras required testing in order to determine the feasibility and digital modelling to decide the placement and number of cameras.

7.3.1 Testing of camera image on human

In order to evaluate infrared technology as a way of identifying dogs and children left in cars a camera test was conducted. The potential risk of a child being invisible to the camera was addressed in the first test.

The test of the infrared camera was conducted using a *Volvo XC60* car and not a *Volvo XC90*. The reason for this was that it was the one that was available for this test. The used *Volvo XC60* were equipped with a black leather clothing and had tinted windows on three of the six windows. The camera used and tested was a *Flir A20M* that had an operating temperature range from -15°C to +50°C, a field of view of 25°x19° with 0,3 meter minimum focus distance and a accuracy on ±2°C or ±2%.

In order to test the camera in a hot environment and to simulate a real situation the temperature of the car was increased using an external heater. This heater was regulated manually. During the test an external LCD portable MULTI-thermometer was also used. This thermometer was used in order to keep track of the temperature inside the car while heating it up with the heater and was placed in the middle of the car between the front seats. The camera was tested in five different temperatures; 23°C (room temperature), 30°C, 37°C (body temperature), 40°C and 48°C (with a deviation of up to maximal $\pm 0,5$°C) and in two different colour ranges for each temperature, one called *Rain* and another called *Midgrey*. Each temperature was also tested using different temperature range settings of the camera, this in order to check which setting of the camera was best suited for the tested temperature.

During the test a human with regular body temperature was placed inside the car for each temperature measured, together with the infrared camera, the heater and the thermometer. The human had to adjust the temperature inside the car using the heater and the thermometer. For each temperature and each temperature range two pictures were taken, one with each colour range. These pictures were evaluated after the testing, checking which setting on the temperature range and which colour range that was best suited for the temperature inside the car. The test resulted in a better understanding of what features and specifications an infrared camera needs to have for being used in the system.

The figures below are the results from the images captioned with the infrared camera. The first row consists of images with the *Rain* setting and the second row with the *Midgrey*. The columns are the different temperature ranges tested, 10-40°C, 10-70°C, 25-50°C, 30-45°C and 30-70°C.

In room temperature (23°C) the range of 10-40°C provided the best picture combined with the *Rain* setting, see figure 7.2 row 1 column 1.

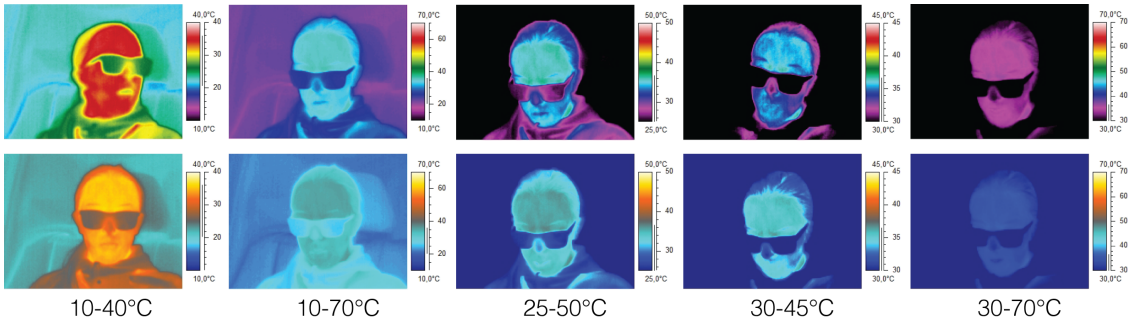


Figure 7.2: Camera images, human in car at ambient temperature 23 degrees

When the temperature reached 30°C the lowest range of temperature was not sufficient, but rather the range of 25-50°C provided the best picture, also combined with the *Rain* setting, see figure 7.3 row 1 column 3.

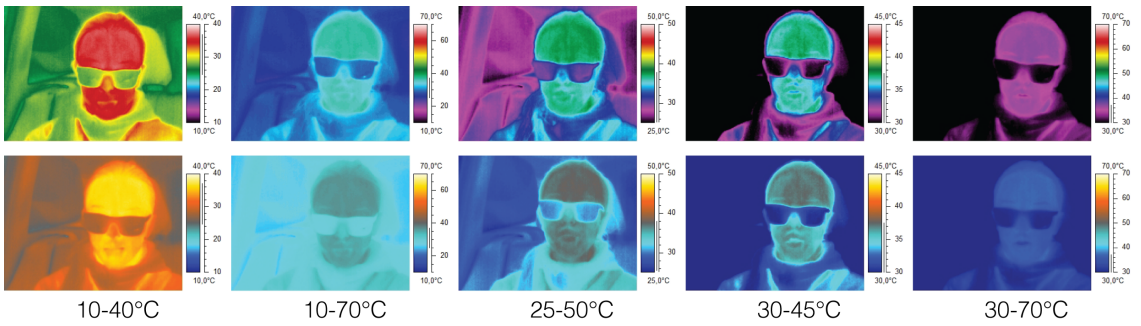


Figure 7.3: Camera images, human in car at ambient temperature 30 degrees

At body temperature (37°C) a more narrow range of temperature was required to make out the human in the picture. The body has almost the same temperature as the surroundings, and the rage of 30-45°C provided accuracy enough, also combined with the *Rain* setting, see figure 7.4 row 1 column 4.

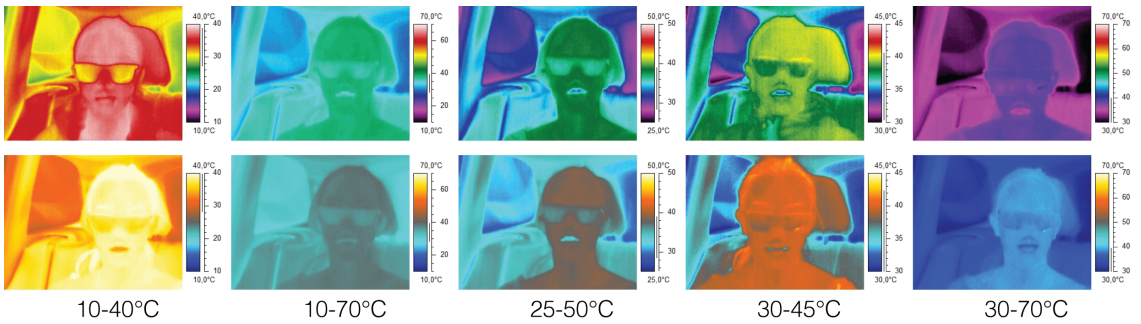


Figure 7.4: Camera images, human in car at ambient temperature 37 degrees

At 40°C the car has started to turn hotter than the human inside, and there is less of an issue with the human being almost undetectable. Again the range of 25-50°C

provided the best picture, also this time combined with the *Rain* setting, see figure 7.5 row 1 column 3.

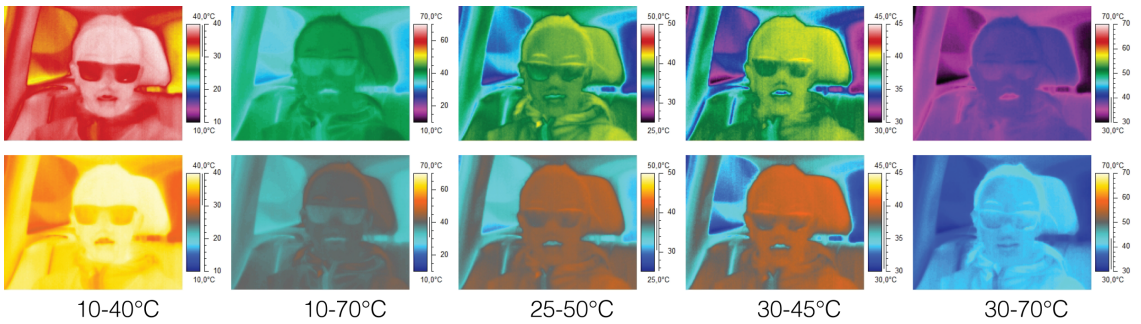


Figure 7.5: Camera images, human in car at ambient temperature 40 degrees

At 48°C, the maximal temperature allowed by the camera, the lower ranges of temperature measured made the human completely invisible. This time again, the range of 25-50°C provided the best picture, as with all cases combined with the *Rain* setting, see figure 7.6.

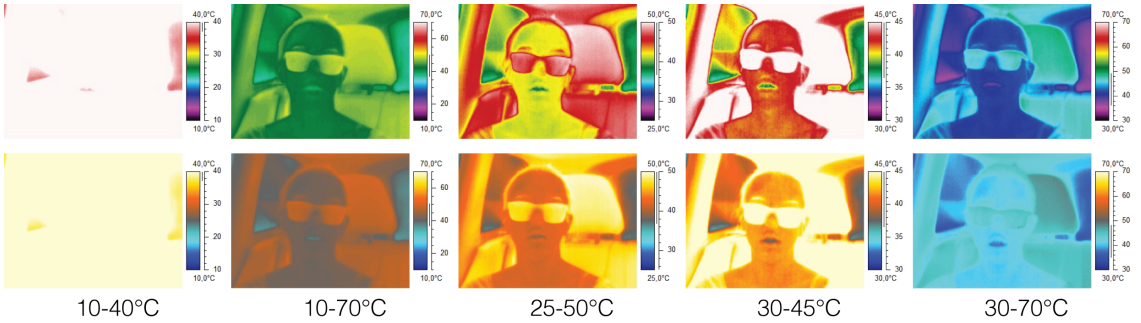


Figure 7.6: Camera images, human in car at ambient temperature 48 degrees

7.3.2 Testing of camera image on dogs

The testing of camera image on dogs was conducted in the same way and with the same equipment as for the testing of camera image on human, see section 7.3.1. The only changes for this test were that instead of testing on a human, dogs with different breeds, see table 3.4 in section 3.4.3, were used and only one colour range *Rain* was chosen to be used during the testing due to the fact that it performed best on all temperatures. In the images Dog1 is presented at row 1 Dog2 at row 2 and Dog3 at row 3.

During the test a heater was started inside of the car, and when the car had reached the desired temperature, +1,5°C to compensate for heat loss when entering the car, the dogs were placed one by one inside together with a human. When measuring temperatures above 30°C the heater was kept on in order to compensate heat loss through the gap of the door where cables entered.

The amount of time the dogs were inside the car was no longer than 3-4 minutes per measured temperature and they were monitored by the human inside for any sign of panting. Between the measurements the dogs had access to a cool area with water.

The figures below are the results from the images captioned with the infrared camera. Each row consist of images on the different breeds. The columns are the different temperature ranges tested, 10-40°C, 10-70°C, 25-50°C, 30-45°C and 30-70°C.

In room temperature (23°C) the range of 10-40°C provided the best picture, see figure 7.7 column 1.

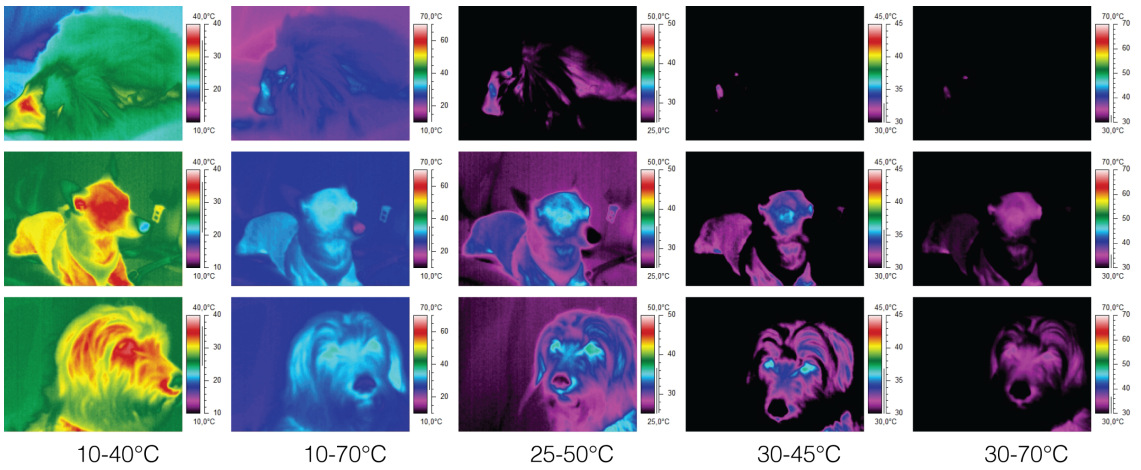


Figure 7.7: Camera images, dogs in car at ambient temperature 23 degrees

For the temperature 30°C the range of 25-50°C provided the best picture for all the different breeds, see figure 7.8 column 3.

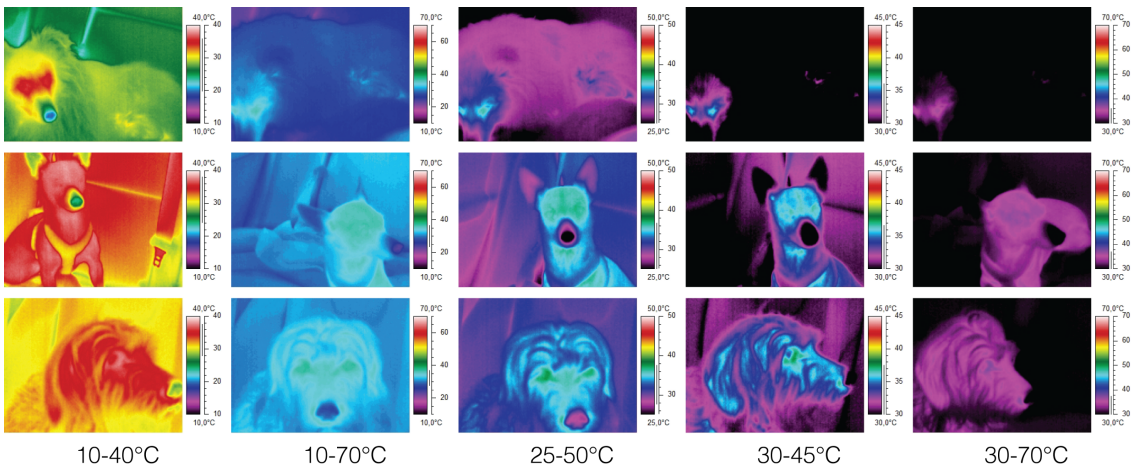


Figure 7.8: Camera images, dogs in car at ambient temperature 30 degrees

At 37°C the range of 25-50°C was still noted to be the best setting that provided the best image with the reservation that Dog1, see figure 7.9 row 1 column 3, might be invisible.

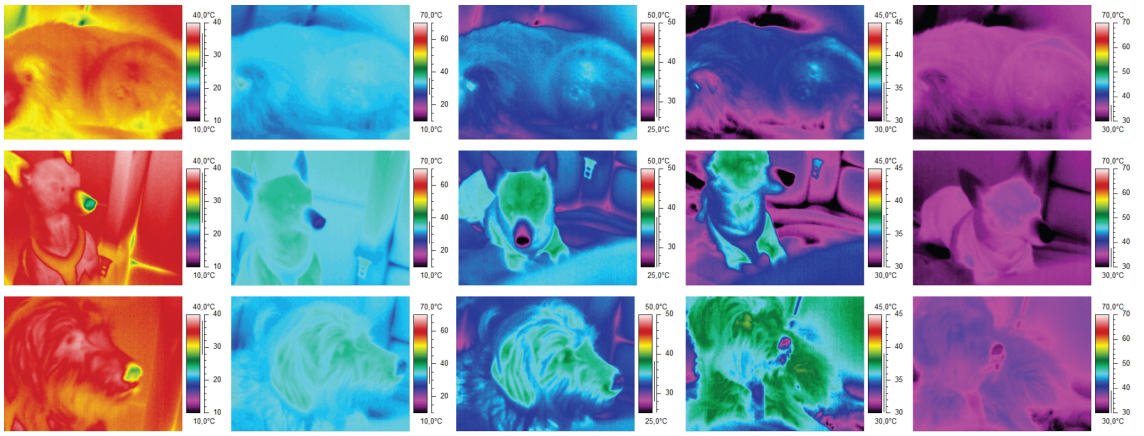


Figure 7.9: Camera images, dogs in car at ambient temperature 37 degrees

At 40°C the range of 30-45°C was the one that provided the best image. However two of the dogs, see figure 7.10 row 1 and 3 column 4, was placed close to the camera making it hard to distinguish them from the background.

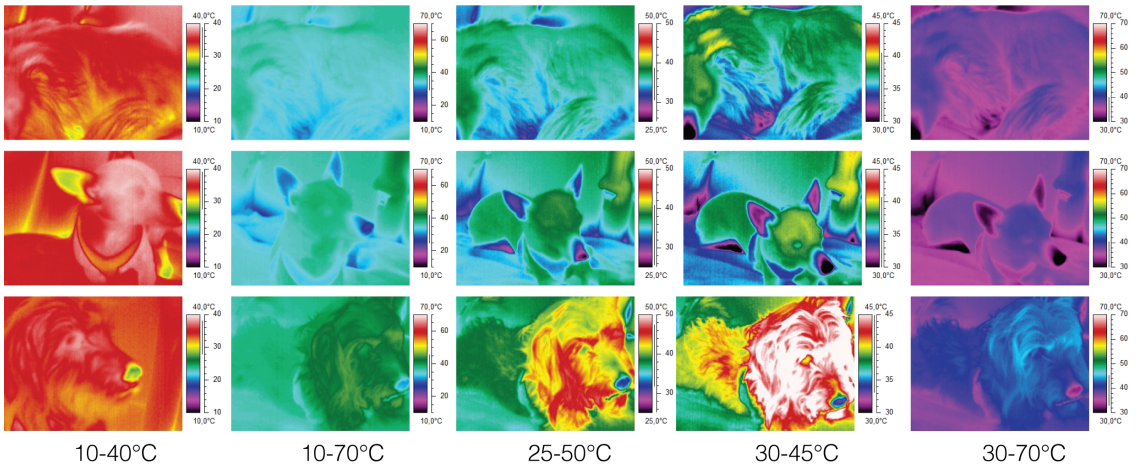


Figure 7.10: Camera images, dogs in car at ambient temperature 40 degrees

For the temperature 48°C there were different settings that could work best in order to get the best picture. For the dog in figure 7.11 row 1 column 1, the range 10-40°C worked best while Dog2 and Dog3 probably would be invisible with this setting. In order to prevent dogs from being undetected at this temperature, the additional motion detection that is currently installed in the car should be used. But the risk of being undetected will be small, since the temperature of the car will not increase to 48°C instantly, the dog will still be detected before at lower temperatures.

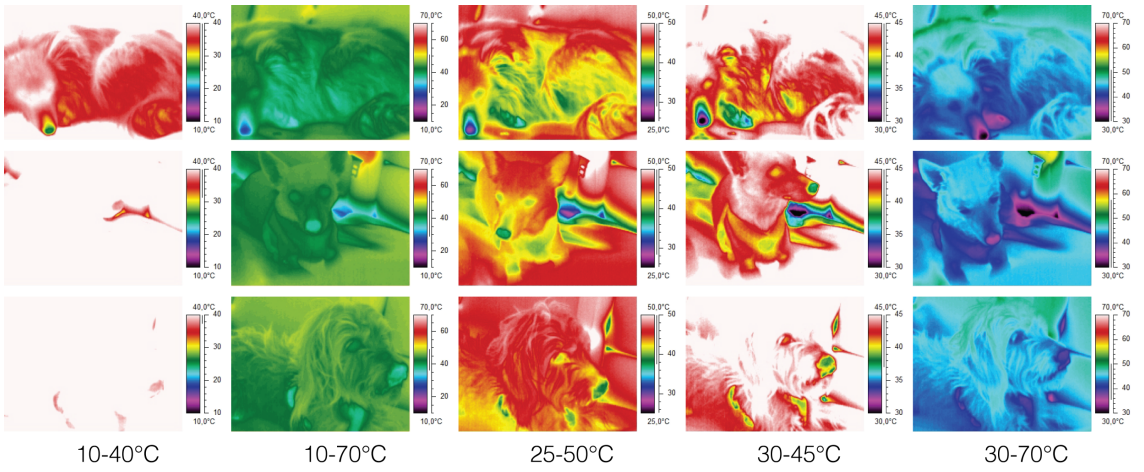


Figure 7.11: Camera images, dogs in car at ambient temperature 48 degrees

7.3.3 Camera settings for detection of human and dogs

As a conclusion based on the measurements by the *Flir A20M* the software connected to the camera needs to adjust the measured temperature range according to the current temperature inside of the car in order to get an accurate enough image, see table 7.1. The critical temperature where the car is close to body temperature requires greater accuracy in the measure range. The best measure range differed a bit between humans and dogs, so it is necessary for the camera to switch measure range, using both settings when trying to detect if anyone is left inside of the car. It can be noted that dogs with different fur types may be invisible for the camera at different temperatures, due to different insulation properties of the fur. Therefore it is important that the camera continue to check for the presence of a dog or child as temperature rises.

Table 7.1: Adjustment of temperature measure range for infrared camera

Temperature in car	**Best measure range human**	**Best measure range dog**
<30°C	10-40°C	10-40°C
30-36°C	25-50°C	25-50°C
37-39°C	30-45°C	25-50°C
40-50°C	25-50°C	30-45°C
>50°C	25-50°C	10-40°C

7.3.4 Placement of cameras

To determine the camera placement a mock-up model of the *Volvo XC90* interior was created using *Autodesk Alias AutoStudio 2016* and *Catia V5*. Drawings of the *Volvo XC90* provided by *Volvo*, measurements made in a car at a car dealer and photos were used as references. In addition to the car interior two different child car seats were modelled, one baby seat (with a hood) that is usually placed backwards in the car and one seat that is used for children up to the age of five. Two dog cages

were modelled as well, based on the leading brands in Sweden, *Proline* and *MIM Construction*, in their large variants. These dog cages were selected due to their large areas of fully covered walls, which could prevent the camera from detecting the dog inside. For the child car seats and dog cages reference photos and measurements provided by retailers were used.

In *Autodesk Alias Autostudio 2016* cameras were placed and adjusted to provide views of all relevant areas inside of the car. In addition to placement and rotation the angle of view was adjusted. One set-up utilised the current maximum angle 90° found on the leading manufacturer *Flir's* homepage *www.flir.com*. As an alternative set-up the number of cameras was minimised by allowing wider angle of views up to 130°.

When deciding the placement of the cameras the possible places where children or dogs could be located in the car were considered. Dogs can be either on the seats, floor, loose in the trunk or inside of a cage placed in the trunk. Children can be placed on the seats, either forward facing or backwards facing, or possibly on the floor if they are unbuckled when left alone.

Camera set-up current common maximum field of view 90°

Research on infrared camera manufacturers during email conversations and information provided on their webpages shows that the current maximum field of view of infrared cameras is commonly 90°. Using the common current maximum field of view found at leading manufacturer *Flir's* homepage *www.flir.com* nine cameras were required.

Camera 1 and 2, see figure 7.12, aim at providing images of humans or dogs placed in the back seat of the car or on the floor. Camera 3 and 4 (not presented in the figure 7.12 but is identical in placement to camera 3) provide images on any child in a backwards facing seat. Camera 5 and 6 provide images of the floor in the front of the car, as well as any forward facing child car seat in the front. Camera 7 provides a regular view on the seats in the front. Camera 8 is placed inside of the trunk lid, and are the camera that manages to provide pictures inside of dog cages with covered roofs. Camera 9 provides a top view of the third seat row or a top view of the trunk if a dog is placed without a cage.

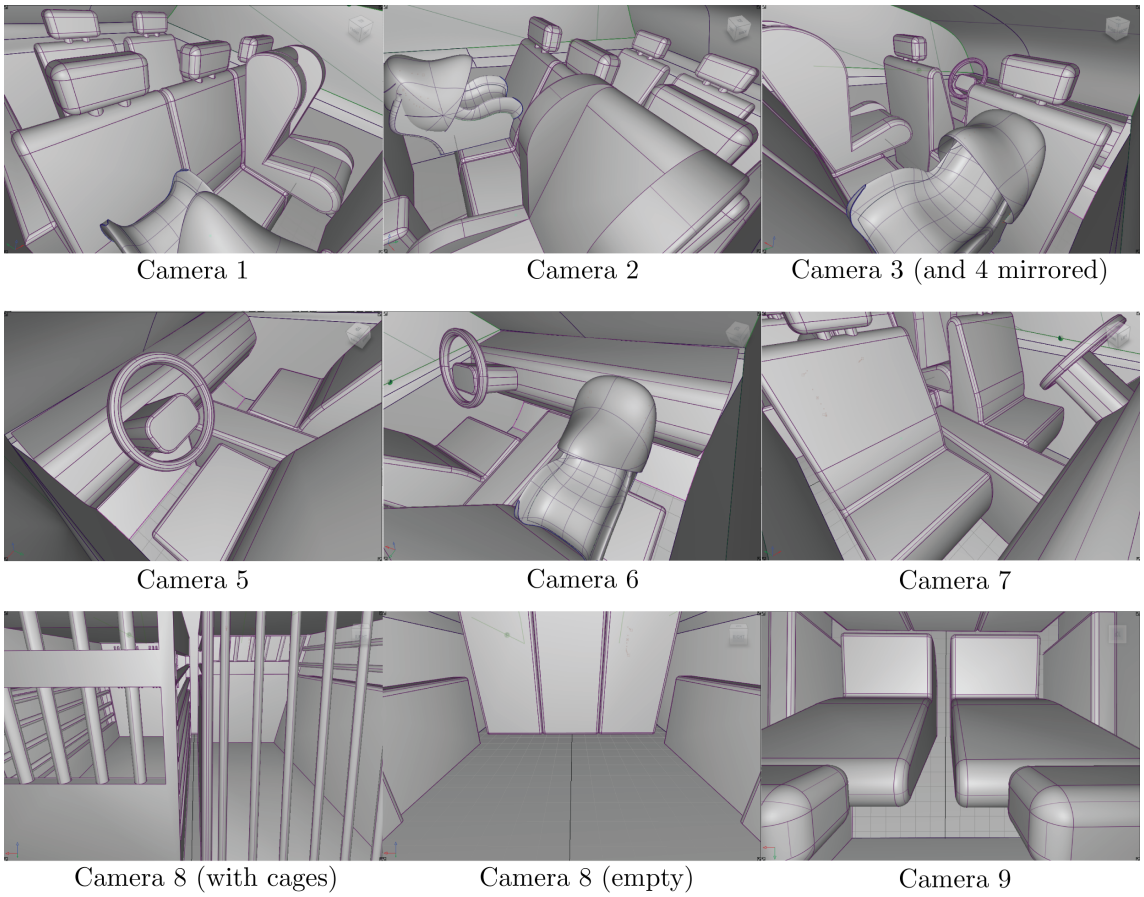
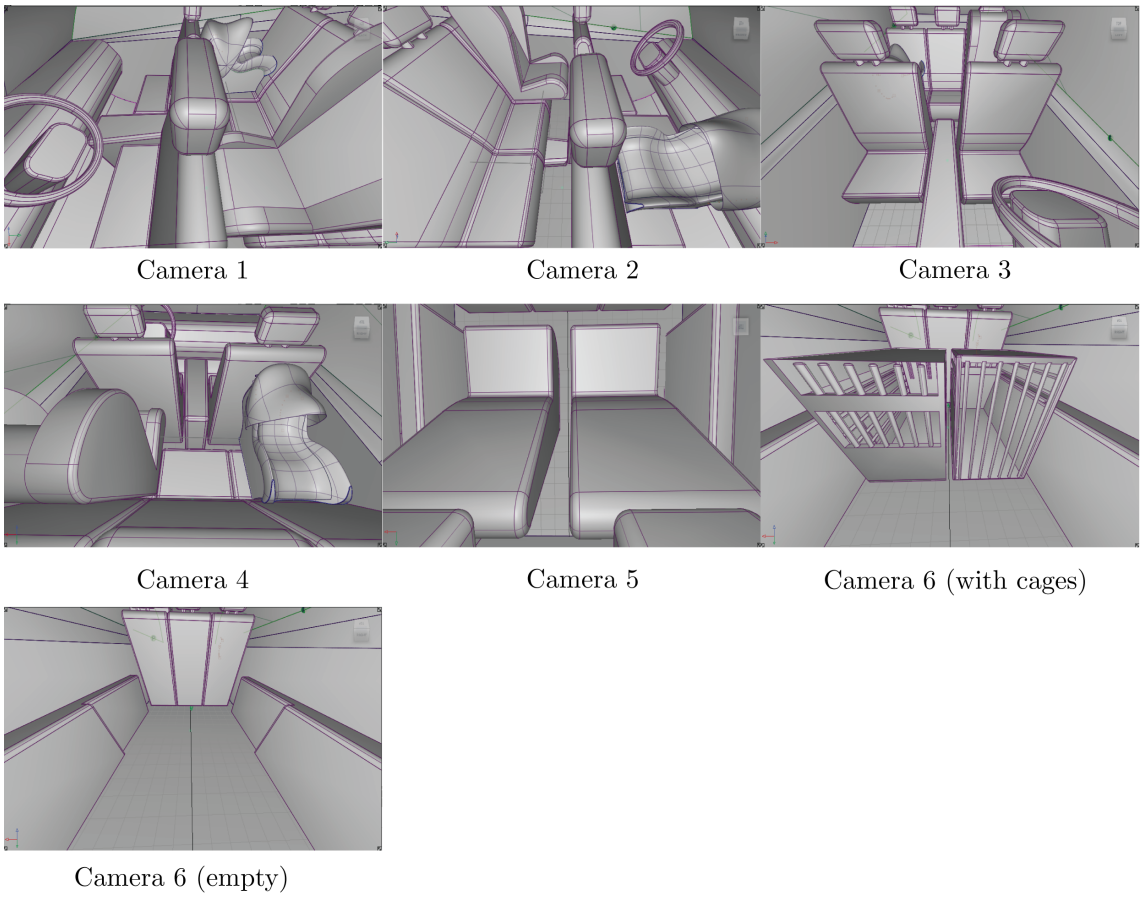


Figure 7.12: Camera images, 90° field of view

Camera set-up optimised angles

When minimising the amount of cameras required the number was reduced to six cameras, but in order to achieve this a field of view up to 130° would be required. This is not something currently available in infrared cameras.

Camera 1 and 2, see figure 7.13, provide views on the floor in the front and back of the car, the back seat and any backwards facing child car seat in the front. Camera 3 gives a view of the front seats, and the floor directly below those seats. Camera 4 gives a view of any backwards facing child car seat in the back seat. Camera 5 gives a view of the trunk, and if the third seat row is unfolded a view of those. Camera 6 is located inside of the trunk lid, giving pictures from inside potential dog cages with covered roofs.



Camera 1 Camera 2 Camera 3

Camera 4 Camera 5 Camera 6 (with cages)

Camera 6 (empty)

Figure 7.13: Camera images, up to 130° field of view

7.4 Mobile application

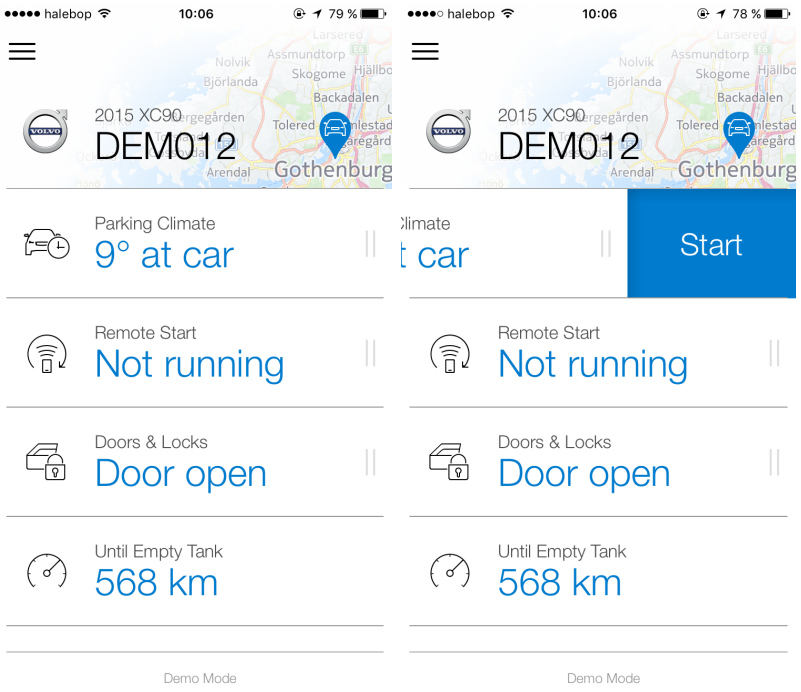
The HeatSafe system is supposed to be integrated in the mobile phone through the *Volvo On Call* application, see section 2.12.3. In order to determine if the application had sufficient usability a small usability test was conducted on a demo of the application. After this the new feature was designed.

7.4.1 Evaluation of Volvo On Call

The HeatSafe system is a critical safety system, and therefore it is important to evaluate if the application has good enough usability to host the system, or if changes are necessary. The results from the tests were also used in the implementation of the new functionality. The *Volvo On Call* application was evaluated through an *iPhone* demo version with six short usability tests, see table 3.5 in section 3.4.6. The participants used the application to perform four scenarios, using functions such as the parking climate, sending a destination to the car, warnings and locking the doors. Before using the application the participants responded to a questionnaire on the symbols used in the application, guessing their meanings.

The conclusion of the test is that the application has sufficient usability to be a host of the HeatSafe system. It was concluded that it is important that the symbols are clear, but even more important that the text in combination with the symbols clearly states the function intended.

The *Volvo On Call* application consists of a home screen wh ere the most important functions are presented. Through this screen a swipe can be accessed for most function, allowing a quick way of starting them, see figure 7.14.

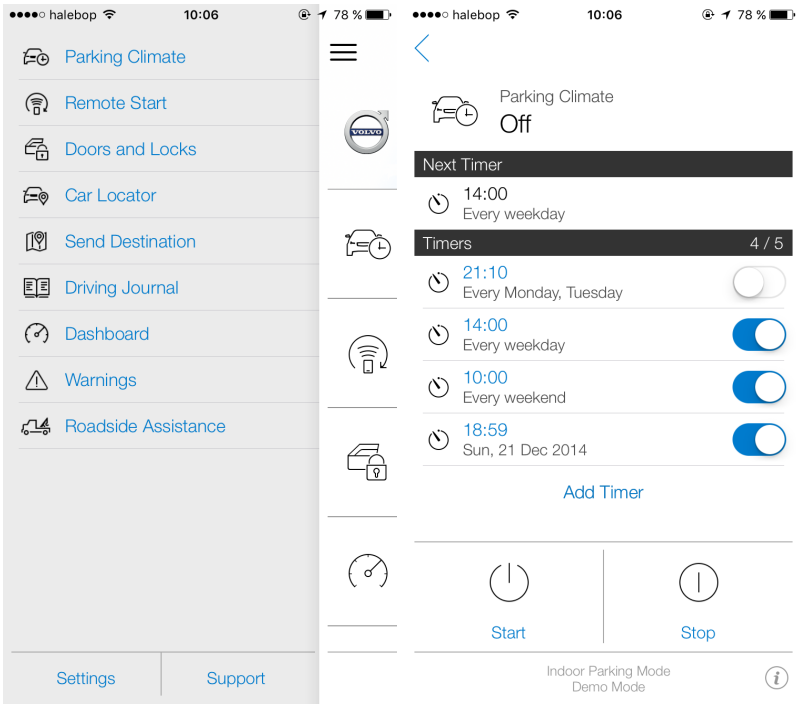


(a) Home screen **(b)** Swipe

Figure 7.14: Volvo On Call application home screen

Source: *Images used with permission from Volvo Cars.*

The home screen provides access to a side menu with additional functions, most functions can be accessed through either the home screen or this side menu, see figure 7.15.



(a) Side menu **(b)** Function menu

Figure 7.15: Volvo On Call application example features

Source: *Images used with permission from Volvo Cars.*

General impressions

Almost every test participant managed to solve all four of the tasks without any help or hints. TP2 needed a hint in order to find the side menu of the application during the task of locating the warnings. All participants had a good impression of the application, considering it easy to use despite it being the first time for many of them.

Due to the first time usage many would feel the need to go to the car in order to check if the functions used did work properly. They did get feedback on their actions and thought that it was sufficient enough, but they still did not have full trust on the application. People had no trouble knowing where they had navigated in the menus.

Symbols

In the first survey the participants had trouble understanding the meaning of the symbols. None of the participants understood the remote start symbol, and the parking climate symbol was not fully understandable. The participants did get the timer aspect of the parking climate, but not that it had to to with the climate system of the car. The rest of the symbols were more clear to the participants. TP2 stated that the symbols made the application look nicer compared to applications

with less symbols. The participants stated that they used the text in combination with the symbols to understand their meaning.

Menu structure

In the application most of the functions can be activated through three different approaches, a swipe on the home screen, entering the function menu through the home screen or entering the function menu through the side menu. All test participants used the home screen primarily to access the function menus in order to perform all of the tasks.

TP1, TP3 and TP5 did use the swipe for locking the doors, while TP2, TP4 and TP6 preferred going to the function menu through the home screen and did not notice the swipe before being told about it.

Functionality

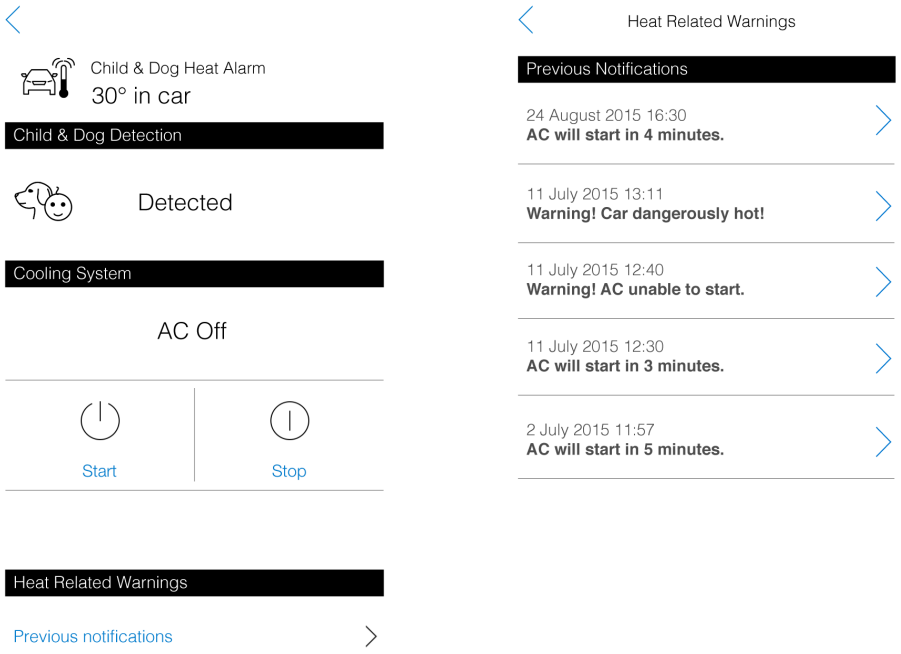
There were a bit uncertainty regarding the functions, the parking climate function was not completely understandable to the test participants, and they were uncertain whether the function actually was what they thought it would be or not. The only function that was not very intuitive was the warnings. In order to find information about for example the washer fluid in the car all participants except from TP5 searched in the dashboard function menu before looking in the warning menu.

The loading bar present at the bottom of the screen after starting a function was understandable, but perceived as slow. In general the number of steps necessary to reach the different functions were perceived as small, and all functions were reached quickly.

7.4.2 Design of HeatSafe application interface

When designing the HeatSafe feature inside of the *Volvo On Call* application the current aesthetics of the symbols, text and the menu structures were used as a foundation. The feature includes an add-on to the home screen of the application, an add-on to the side menu, one function menu, one additional menu with the previous heat related warnings and a connection status definer at the home screen. The created feature in the application is presented using the *iPhone* operative system.

The function menu, see figure 8.9a includes information about the current temperature inside of the car, whether a child or dog is detected inside of the car, a way of starting the AC manually if desired, and access to previous warnings. The previous warnings menu, see figure 8.9b include all previous heat related warnings, and allows the user to read the notification messages again.



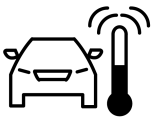
(a) Function menu **(b)** Previous warnings

Figure 7.16: Feature menus in application

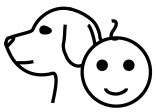
Symbols

In the design of the symbols the current symbols in the application were used as a foundation. With brainstorming suggestions for the main function symbol (indicating the Child & Dog Heat Alarm), as well as the symbol for indicating if a dog or child is identified in the car (Child & Dog Detection) were designed.

The main function symbol, see figure 7.17a, pictures a car and a thermometer with two curved lines on each side of the thermometer indicates an alarm. The detection symbol, see figure 7.17b, pictures the profile of a dog, and the face of a baby in simple style.



(a) Main function symbol



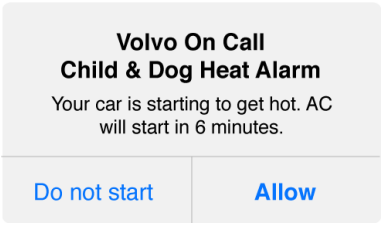
(b) Detection symbol

Figure 7.17: Designed symbols for application feature

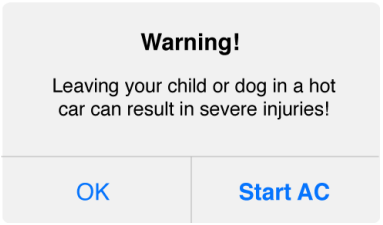
Information and notifications

The text based information was inspired by the current information provided in the *Volvo On Call* application. The text based information serves as the primary information source, as can be seen in figure 7.16.

When notifying the user on the status of the system three notifications are possibly sent, one notification informing the user that the AC will start, one informing the user that the AC has a malfunction, and one informing the user that the car has started to become dangerously hot. These are sent to the user with appropriate timing depending on the GPS data, allowing the user to return to the car in time. The notification informing the user that the AC will start gives the user the option to allow it or not, if the user does not allow the AC to start an additional notification informs the user on the dangers with heat and gives an additional option to allow the AC to start, see figure 7.18. The reason for choosing these kind of notifications where the user still has the possibility to actively start the AC is due to legal restrictions that could be an issue when having the car fully automatically start the engine when running the AC on the diesel or petrol version. However, should the user not select any of the two options the system still needs to start the AC anyway.



(a) AC notification



(b) AC "Do not start", follow up warning

Figure 7.18: Notification examples

Sound and vibration

The sound and vibration is a way for the application to make the user aware of the incoming notifications. A brief definition of the characteristics of the different sounds and vibrations can be found in table 7.2.

Table 7.2: Sound and vibration definition

Notification	Sound and vibration
AC start	Single notification, optional sound and vibration.
AC "Do not start" follow up	Single notification, optional sound and vibration, notify again if not read.
AC malfunction	Single notification, forced sound and vibration, notify again if not read.
Heat danger	Lasting notification, forced sound and vibration, not able to turn off message and sound immediately. Sound and vibration intensity ensuring attention.

7.5 Software

The software controls the different hardware components, both the currently installed thermometer, GPS and AC, and the new additions with the *Volvo On Call* application feature and the infrared cameras. In figure 7.19 the whole system process is described, with all actions and condition based actions that the software needs to be involved in.

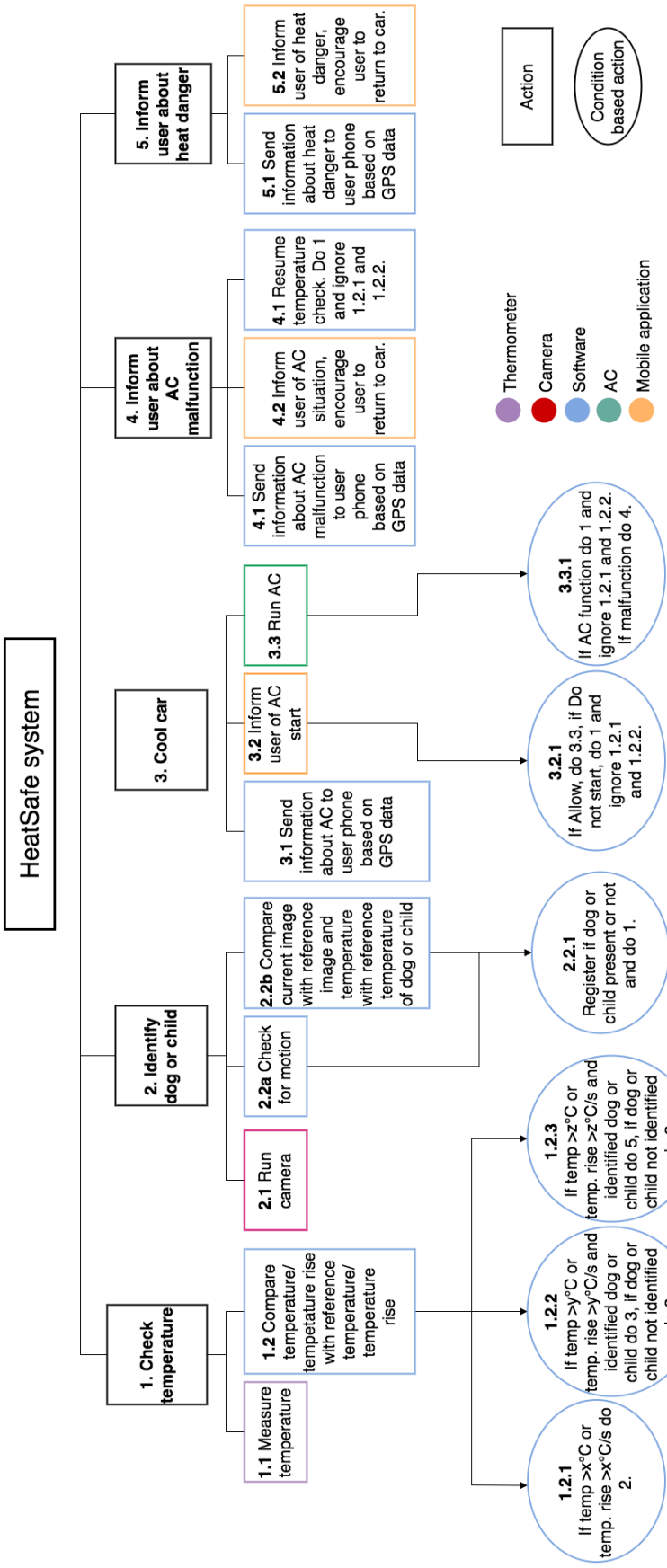


Figure 7.19: Flowchart of system

7.6 Economical feasibility of HeatSafe system

The element of the HeatSafe system that will determine the cost of implementing it in cars will be the infrared cameras. Depending on the amount of cameras needed, nine or six, the price will vary. Since the current found available cameras in most cases only gives a 90° field of view the additional field of view needed to lower the number of camera would probably be costly.

No accurate number of the cost of using the current available cameras with 90° field of view in cars have been found. The only available costs after corresponding with company representatives of three infrared camera manufacturers have been regarding ordering a few units. When implementing cameras in cars the volume would be significantly larger, so these available costs can not be seen as accurate. The price for ordering *Flir Tau 2*, one suitable camera model provided by the leading infrared camera brand *Flir*, would be approximately $3477 per unit according to an e-mail conversation with a company representative but no pricing could be estimated for large scale batches.

7.7 FMEA

In order to evaluate the potential errors and their causes and effects an FMEA was conducted (see appendix T). In total 44 errors were listed, with the RPN severity ranging from 20 to 630 (the possible minimum being 1 and possible maximum being 1000). Among these errors 16 errors that scored above 100 RPN, while having the project group listed as responsible were selected as most relevant. These are presented below in table 7.3.

Table 7.3: Extract from FMEA

Potential Failure Mode	**Recommended Action(s)**
Unable to distinguish living being from background.	Select camera with sufficient accuracy, proper programming. Use additional system (air motion) to detect living being.
Unable to detect position of user.	Send notifications with default timing. Select components with lasting performance. Service of software related hardware regularly. Correct programming.
Camera vision impairment.	Service of cameras, provide warning to user if a camera has vision impairment.
No battery power or petrol/diesel.	Provide warnings to user that AC is unable to start, provide warning that battery/petrol/diesel needs refilling.
AC hardware error.	Regular service, testing, provide warning to user.

Phone turned off.	Ensure AC starts anyway.
Phone not connected to car (while turned on).	Ensure AC starts anyway.
Application not installed in phone.	Car display can remind user to install application. Include optional compatible phone when buying car.
Wrong language settings in application.	Separate setting in application for language.
User unable to interpret information.	Start AC automatically. Ensure that information provided is comprehensive.
User ignores notification.	Start AC automatically, make information comprehensible and distinguishable in notification.
Vibration and sound not working.	Start AC anyway.
Dog or child covered by object.	Start camera often, provide information on non-detected living being in application.
False alarm on motion.	Automatically close windows if open and suspecting living being inside of car to determine if wind or not.
False alarm from non-living object.	Check for motion.
User decides not to return to car.	Provide information that clearly expresses severity, provide number to call for help in application.

7.7.1 Updates according to FMEA

The final concept was created with adjustments based on the FMEA, found in table 7.3. Most of the recommended actions are already incorporated in the elements of the HeatSafe system. Some actions are not implemented, and are left for further development, but two were implemented in the final concept:

- Send notifications to phone with default timing should the GPS data be missing.
- Software and camera check with regular intervals for signs of living being should the temperature in the car rise and none has been detected.

7.8 Detailed element requirements

In table 7.4 below the more general element requirements from section 6.5 are developed and interpreted to requirements with desired target values. The values and units left empty are in need of further research.

Table 7.4: List of detailed element requirements

Element	Requirement	Value	Unit
Infrared cameras	Number of cameras	6/9	Pcs
Infrared cameras	Operating temperature	0-100	°C
Infrared cameras	Storage temperature	-40-100	°C
Infrared cameras	Field of view	130/90	°
Infrared cameras	Focus distance	<0,3	m
Infrared cameras	Thermal sensitivity (image)	≤0,12 at 30	°C
Infrared cameras	Palette colour range		
Infrared cameras	Humidity resistance		%
Infrared cameras	Vibration resistance		%
Infrared cameras	Shock resistance		
Air condition	Legally allowed operating time		minutes
Air condition	Power required	2000	Watt
Air condition	Emissions		CO_2
Mobile application	Be included as feature in Volvo On Call app	Pass	Binary
Mobile application	Provide connection status	Pass	Binary
Mobile application	Show temperature	Pass	Binary
Mobile application	Allow manual start of AC	Pass	Binary
Mobile application	Provide notification inside application	Pass	Binary
Mobile application	Provide notification outside application	Pass	Binary
Mobile application	Sound indication of warning	Pass	Binary
Mobile application	Vibration indication of warning	Pass	Binary
Mobile application	Provide AC status information	Pass	Binary
Mobile application	Indicate that dog or child is left inside car	Pass	Binary
Mobile application	Provide access to previous warnings	Pass	Binary
Mobile application	Inform user of date and time of previous warnings	Pass	Binary
Mobile application	Inform user of circumstances of previous warnings	Pass	Binary
Software	Function according to flowchart, see figure 7.19	Pass	Binary
Software	Adjust settings of camera depending on car temperature	Pass	Binary
Software	Ensure stable functionality	Pass	Binary
Software	Provide fast calculations		Seconds

8
Final concept

In the following sections the final concept is described. This phase, as part of the whole project process, can be seen in figure 8.1.

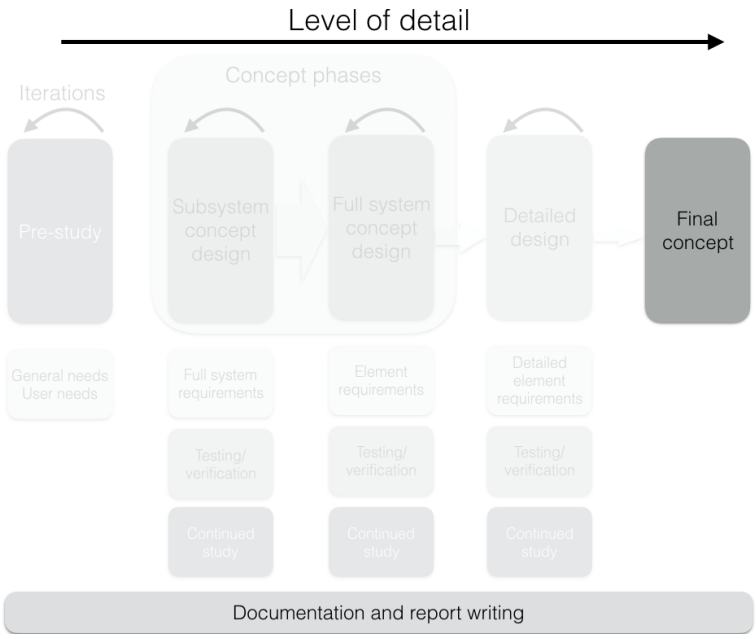


Figure 8.1: Process phase final concept

8.1 System description

If a child or dog is left or forgotten in a *Volvo XC90* the HeatSafe system can both save the child or dog by cooling the vehicle, as well as inform the user on the current situation and its seriousness. When the sun rays enter the car the car could start to heat up. A thermometer, currently placed in the car is registering the temperature. When the car starts to slowly heat up, the thermometer registers that the temperature is not constant.

Installed in the cars are six infrared cameras with between 90° and 130° field of view, see figure 8.2 where five of them are displayed, that are able to see every area in the car. The cameras are represented as dots on the roof in the figure. At this point, when the temperature has started to change, the car software starts the cameras. The software registers the information from the cameras, adjusting the measured

temperature range in the image according to the current temperature inside of the car in order to provide the best image. The image is analysed in order to detect any child or dog left in a car, monitoring objects with body temperature, detecting motion and comparing the image to reference images. Should the cameras not detect any child or dog at this point, the software regularly checks again at intervals if the temperature continues to rise until someone is detected, and also uses the already existing motion detection system of the car.

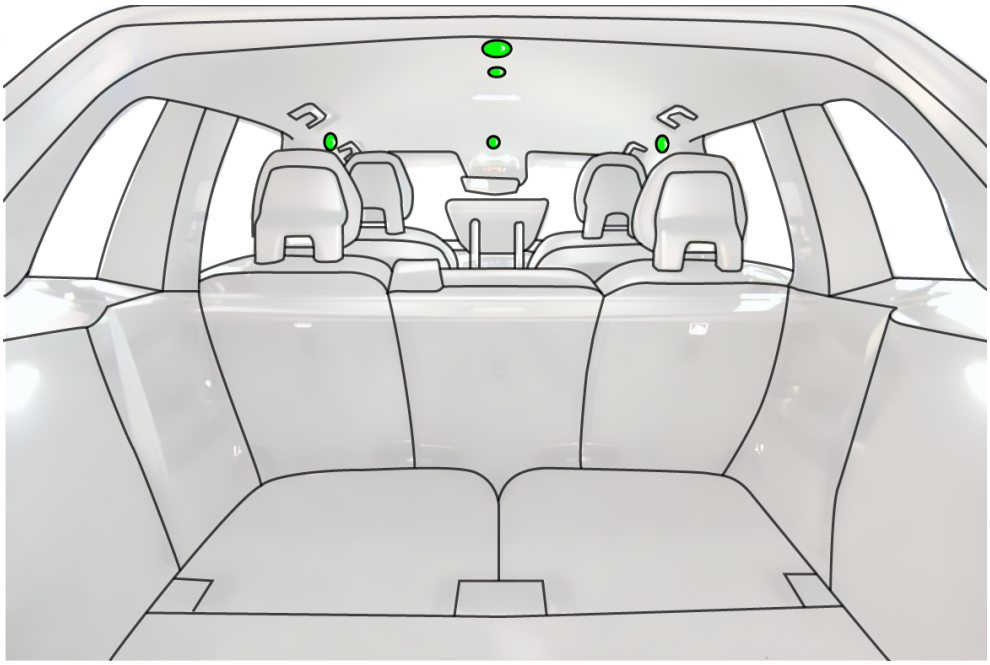
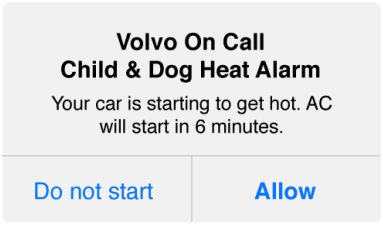
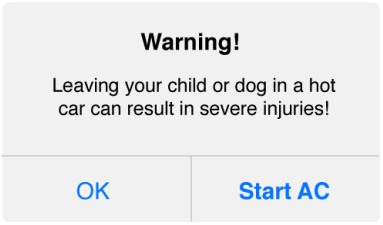


Figure 8.2: Camera placement visualisation

When the cameras have detected a child or dog and the temperature continues to rise the software starts the AC at a point where cooling will be needed in order to prevent future hyperthermia to happen. Before the starting of the AC the user is warned through a notification in their phone provided by the *Volvo On Call* application, see figure 8.3a. The user has the option to either allow the starting or not start the AC. The options are provided in order to give the user perceived control of the system and also in order to minimise the potential legal issues with always having the car starting the AC automatically. Should the user decide not to start the AC another notification follow, see figure 8.3b, warning the user about the dangers with heat and providing a second option of starting the AC. Both of the notifications uses a sound and vibration that is optional to turn off. If the user would not make any choice the car starts the AC automatically anyway. The warning is sent at such a time that the user can manage to return to the car before the AC should start if not desired, based on the GPS data of the phone and car to calculate the estimated required return time.



(a) AC start



(b) AC "Do not start", follow up warning

Figure 8.3: Notifications at AC start

Should the AC be started, but for some reason not function properly, because of a malfunction or if the car has run out of power, the user gets another notification on their phone, see figure 8.4. This is not a common case, but if it happens the user is prompted to return to the car, and the sound and vibration used when delivering the notification should be compulsory and calling for attention.

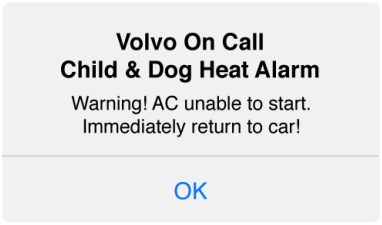


Figure 8.4: Notification of AC malfunction

In the rare cases with a malfunctioning AC, if the user did not allow the AC to start, or some other situation preventing the car from being cooled the temperature may continue to rise. When the software detects a soon to be dangerous rise in temperature with information from the built-in thermometer and/or the infrared cameras, the user is informed through another notification. This notification comes with compulsory sound and vibration designed to make noise and call for immediate attention, and is not possible to shut down immediately. The notification can be seen in figure 8.5, and informs the user that the car is hot and that immediately returning to the car is necessary. In reality the information is sent to the user with a safety time margin, based on the GPS coordinates of the car and phone, making sure that the user can return before the situation gets dangerous. The goal is to get the user back to the car in time for removing the child or dog, while the child or dog is not yet harmed. Should the software be unable to determine the GPS coordinates and calculate an estimated return time the notification is sent with a default timing including safety margins.

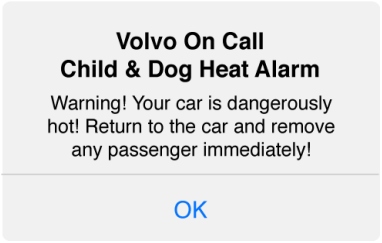
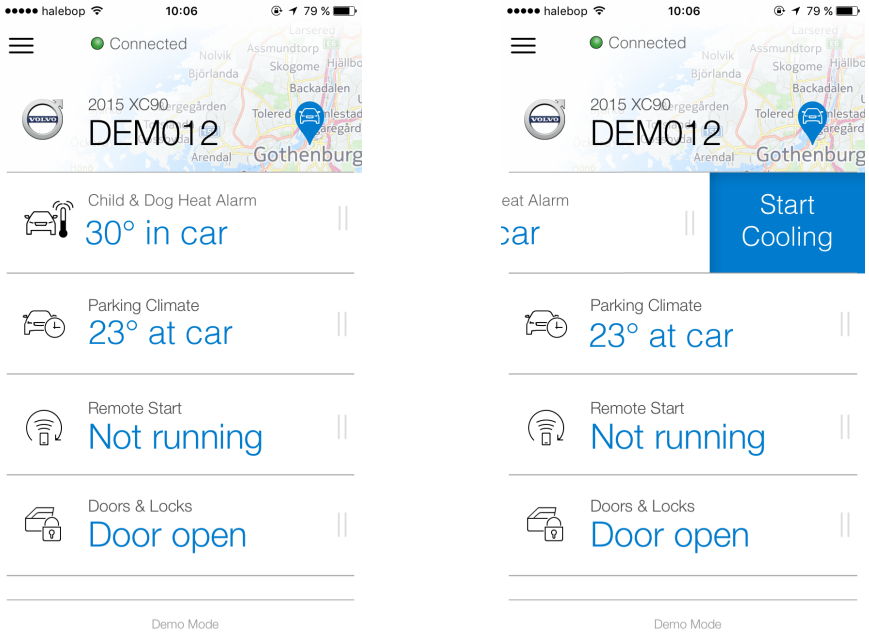


Figure 8.5: Notification sent before dangerous heat situation occurs

If the user wants more information on the current situation inside of the car than the notifications provide the HeatSafe feature in the *Volvo On Call* application could be used.

The application feature is presented in the home screen, see figure 8.6, and is called Child Dog Heat Alarm. In the home screen the user has access to a swipe for a quick way of manually starting the AC should the system not yet have started it, or if for some rare reason a child or dog is undetected but the user knows it is left in the car. At the home screen the current interior temperature is presented, as well as a connection status.



(a) Home screen with feature

(b) Home screen swipe

Figure 8.6: Home screen with HeatSafe feature

Source: *Images used with permission from Volvo Cars.*

Except from the home screen of *Volvo On Call*, the feature can also be accessed through the side menu. This can be seen in figure 8.7.

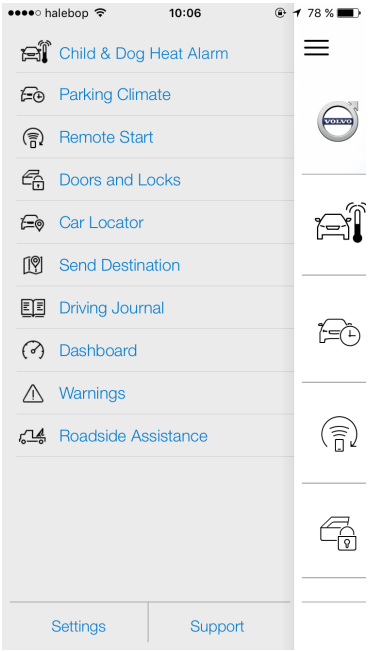


Figure 8.7: Home screen side menu with HeatSafe feature

Source: *Images used with permission from Volvo Cars.*

If the user wants access to more information than the temperature, and more possible actions than starting the AC, the user can enter the feature's function menu, see figure 8.8. Here the user can see information on whether a child or dog is detected, the current temperature, the AC status (as well as the possibility to control the AC manually before it has been started automatically), and the previous notification warnings sent to the phone.

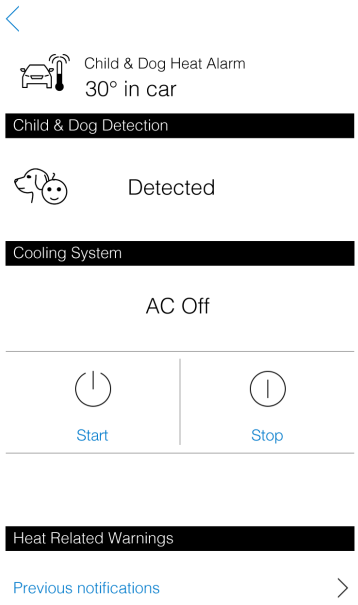
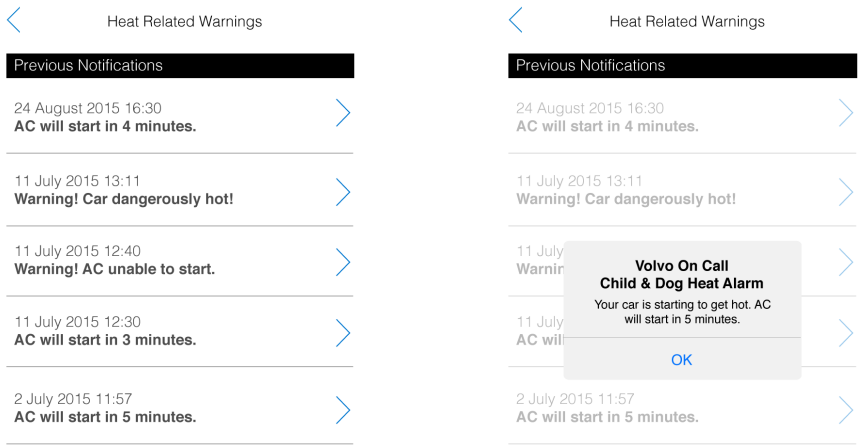


Figure 8.8: Function menu HeatSafe

When moving into the previous warning notifications menu, see figure 8.9 information is provided with date and time of warnings, and a summary of the content. To get the full information the user are able to click on the warning to get the notification pop-up presented.



(a) Previous warning notifications menu

(b) Previous warning example

Figure 8.9: Previous warnings menu

With the current legal issues there is a possibility that the car will not be able to start the AC automatically should the user not respond to the notifications sent through the phone. Therefore the first version of the HeatSafe system could be implemented in the hybrid vehicles, where the AC do not require an engine start.

9
Discussion

In this chapter the results of the project are discussed, starting with a discussion about the methodology. After follows a discussion about the risk compensating behaviour that could possibly occur among users of the system. Finally areas in need of further development are listed, and a list of alternative applications of the infrared cameras installed in the system are presented in order to increase the value of the system.

The project resulted in a design of a conceptual HeatSafe system that is plausible to implement in future cars. In the current situation the infrared cameras are too expensive, but with further research and adaption the system could be implemented in full scale. The technology is feasible, since infrared cameras with the required properties do exist. Therefore the purpose of the thesis can be considered as fulfilled, and there is a possibility of using the system in the future even though it might not be possible cost wise to implement immediately.

In the thesis the current situation with problem description is defined with the results from the studies conducted, and through the different needs and requirement lists. The interviews with dog owners, parents, veterinarians and paediatricians as well as the other research during the project have given an insight on what the problem is and how it occurs. The problem is essentially based on the human behaviours and therefore the HeatSafe system is designed to function regardless of human behaviour in order to save lives. The developed system works in different situations, regardless of the users intentions, if the child or dog is forgotten or left on purpose.

9.1 Methodology

In this section the methodology of the thesis is discussed. The section is divided in subsections based on the different phases of the project, where the methods and method implementations of each phase are reviewed.

9.1.1 Pre-study

The pre-study aimed at gathering information about the *Volvo XC90*, the users and the medical situation of the problem. The used methodology was interviews, questionnaires, a literature study and benchmark. These different methods complemented each other, giving an overall picture of the problem.

It is hard to know if the questionnaires reached the more risk taking target group. Few parents answered the questionnaire and almost no men did answer. This is an issue since men are generally more risk taking than women (Byrnes, Miller, and Schafer, 1999). Also, there is a possibility that the people who answered the questionnaire were people who are actually aware of and interested in the problem with heat related illness in children and dogs, at least they state that they are. The group of people who are not aware of the problem and not interested in it may not have been reached. There is a similar situation regarding the interviews with dog owners and parents. The interviews gave a general view on how it is to be a parent or dog owner, but all participants were aware of the problem with leaving children and dogs unattended in cars. People may not be inclined to admit to leaving their children or dogs in dangerous situations, so the true target group of the system was not reached in the interviews or questionnaires. Even though the HeatSafe system has been designed to take the less risk aware users in consideration, this results in a need of further studying the behaviours among the risk taking users.

Three different veterinarians were interviewed on medical issues, but only one paediatrician. If continuing the development more interviews with veterinarians and paediatrician on the topic of hyperthermia might not be necessary to conduct, but rather involving veterinarians and paediatricians in evaluating the HeatSafe system to make sure that the medical aspects are considered properly in future development. Also, since only two parents and dog owners were interviewed some user needs might not have been identified due to the relatively few amounts of interviews. This risk was, however, reduced with the user needs questionnaire performed, where no additional needs were suggested by the respondents of the questionnaire.

9.1.2 Subsystem concept development

In the subsystem concept development most of the development work consisted of different versions of brainstorming. It is possible that some solutions were not identified, as the users, veterinarians and paediatricians were not involved in the creative work. A focus group could have provided more solutions and ideas from a non-engineer perspective. The different brainstorming techniques used, with different themes did however work well and boost the idea generation, resulting in more concepts compared to having a standard brainstorming.

When screening the generated solutions at an early stage the experience of the project group members were used instead of formal method such as matrices. There is a risk that this method was not the most accurate, but being critical towards the concepts at an early stage resulted in only feasible concepts being left in later stages, reducing the amount of concepts quickly to not spend time developing concepts that were uncertain.

9.1.3 Full system development

Using Semantic differential interviews to evaluate concepts worked well, and the user input correlated with the needs found in the pre-study. Four interviews might not have been sufficient to get an overall view on the users thoughts about the concepts, so in future development more users should be involved to get a full understanding of their attitudes towards the HeatSafe system. The users did however have the same favourites among the concepts so it is possible that four interviews were sufficient anyway. During the interviews sketches of the concepts were displayed, and while the users seemed to understand the concepts the result could have been more accurate if mock-ups or real prototypes had been displayed instead so additional user tests or interviews using a real system could be beneficial for future evaluations. Also, what the users stated would be their choice among the concepts in theory might not be the same as in real life. When evaluating the final HeatSafe system among users it would be important to not only have them state their thoughts, but rather have them use the system and studying their behaviours.

When evaluating the full system concepts in the Kesselring matrix the results from the interviews, combined with the results from the user needs questionnaire were used as a foundation for the weighted importance set. The responses to the user needs questionnaire rendered a result where almost all needs were considered as very important, so in some cases the importance were set according to the project group's experience from the interviews and pre-study. With this in mind the user needs questionnaire might not have been necessary to perform at all, and a more accurate way of determining the importance of the user needs has to be researched if the needs are to be of use in future development.

9.1.4 Detailed design

In the following sections the parts considered most relevant to discuss from the detailed design phase are discussed. Those parts include the tests conducted with the infrared camera, the estimation of necessary power for AC and the design and testing of the mobile application.

Test of infrared camera

The tests conducted with infrared cameras on human and dogs were not conducted in real conditions. The car was a smaller sized car than the *Volvo XC90*, and was not heated with sun rays but with heat fans. This may have caused uneven air temperature inside of the car, and in one case one of the dogs stayed close to the hot air, making the fur appear hotter than in a real situation. Due to safety issues the test subjects were not placed inside of the car for the whole test, so at each measured temperature the human or dogs had a normal body temperature when entering the car. In a real situation the human or dog would have stayed inside of the car as the temperature rose, giving the skin or fur more time to adjust to the temperature, possibly increasing the risk of being invisible to the camera. Due to the small field of view of the tested camera the dogs were only photographed in the

back seat of the car and not in the trunk.

Since the test required cables to enter the car through the doors, a small gap was present where air could enter and exit the vehicle. During the test the temperature inside was sensitive due to this, and it was not possible to maintain a stable temperature. This was especially prominent when testing the camera at dogs, during the human test the human inside could stay for longer periods of time, operating the heat fan to maintain a more stable temperature. When having dogs inside time was more of an issue, in order not to keep the animal inside of the car for too long periods of time. The thermometer used in the test also might not have had enough sensitivity. When operating the fan the temperature continued to rise for some time after the fan was shut down, and continued to decrease even though the fan had been started.

This results in a need of conducting further studies on infrared cameras, especially using a camera with the required properties. The ethical issues with placing dogs and children in a hot car is a problem, so leaving them inside of the car for longer periods of time might not be possible at all even in future tests. However, improvements in the test circumstances, having the correct car, more accurate ways of heating the car and removing other error sources might be necessary when developing the software that should detect children and dogs.

AC

When estimating the required power in order to run the AC data from previous studies were used. These studies were not conducted within the same circumstances as would be the case with a child or dog being left in a car. One major difference is that the temperature inside of the car that the AC kept in the studies was lower than what would probably be necessary to keep when just aiming at preventing heat stroke. In that case it is not the comfort temperature that is the desired one. In order to determine the true required power complex thermodynamic calculations would have to be conducted, or studies within real circumstances. The current estimated power required was however sufficient for determining the feasibility. When implementing the HeatSafe system in cars with diesel or petrol engines, where having the AC run results in emissions, further research in legal issues needs to be conducted.

Mobile application

Using the mobile phone application as a mean of communicating important information could have drawbacks, which were found in the conducted FMEA (see appendix T). Mobile phones can run out of battery, be forgotten or broken. The system should always start the AC automatically if there is a danger to a child or dog inside of the car and the user has not been possible to contact, but should the AC not function properly the user needs to be informed in order to rescue the child or dog. This issue needs to be looked more into. *Volvo* has announced that they in 2017 will start selling cars with the car key integrated in your phone as an application (Volvo Car USA, 2016).

During the project the *iPhone* version of the *Volvo On Call* application has been used as a reference. In order to release the system further development for usage in android phones (possible adjustments to the interface) could be necessary. Also the design of the sound and vibrations used for each warning notification needs to be decided. The design of the HeatSafe application is not tested by dog owners and parents. To get a realistic view on the user behaviours additional tests should be conducted with dog owners and parents.

9.2 Risk compensation behaviour among user

In studies on driver behaviour the perceived risk has been shown to affect the drivers behaviour. These behaviours are known as risk compensation. This is however something that is in general hard to measure (Phillips, Fyhri, and Sagberg, 2011). A study by Phillips, Fyhri, and Sagberg, 2011, showed that bicyclists usually wearing helmets maintained a higher speed and less risk perception when wearing a helmet compared to when they did not wear helmets. However, among bicyclists not used to wearing a helmet at all the results were similar with and without the helmet.

According to Wilde, 1998 four different utility factors determine the amount of risk that people prefer to take. Factor one and four affect the behaviour most:

1. Dangerous behaviour benefits (such as saving time)
2. Dangerous behaviour costs (such as speeding tickets)
3. Safe behaviour benefits (such as insurance discounts)
4. Safe behaviour costs (such as losing time)

The dangerous behaviour studied in the project is leaving or forgetting a child or dog alone in a car. Forgetting a child or dog could be caused by loads on working memory caused by stress (Ferrara et al., 2013). In contrast leaving a child or dog is probably most often something the user is aware of doing. In relation to the HeatSafe system the utility factor of dangerous behaviour costs will probably be the most affecting one, due to the reduction of the cost of behaving dangerously. Usually when leaving your child or dog on purpose in the car the cost could be hyperthermia or heat stroke, and in worst case death. The preventive measures, such as lowering the windows or opening the trunk lid, comes with the cost of possibly having the child or dog stolen. But when the cost no longer is having your child or dog suffering from heat stroke, or being stolen, you can adjust your behaviour.

When implementing the HeatSafe system, the cost of leaving your child or dog is reduced, since the risk of the user not returning in time to the car, as well as the risk of the car getting hot in the first place are reduced. In order to prevent the user from interpreting the information provided from the application in a way that makes the user comfortable with the situation the information has been delivered as warnings. This is a way of reducing the dangerous behaviour benefits that otherwise come with the system (not having to remove child or dog from car), and instead trying

to make the user feel guilty about the situation, as a cost of the dangerous behaviour.

In order to determine the user risk compensation behaviour further studies of the system would have to be conducted when having it installed in test vehicles. Conducting studies with a theoretical case, having the participants reflecting on how they would or would not change their behaviour might not be accurate enough.

9.3 Interferences with car of passersby

The HeatSafe system will not be visible outside of the car it is installed in. In the cars where the AC is powered by the diesel or petrol engine the sound of the engine will be possible to hear, and possibly the sound of the AC running inside of the car.

The invisibility of the system results in the risk of passersby drawing the conclusion that the child or dog inside is in danger, and therefore taking actions such as breaking the windows of the car. During the pre-study it was concluded that people are not keen on braking the window, but would prefer to find the parent or dog owner first. The passersby could see that the child or dog is not screaming or panting, but in the cases where they are asleep it would be hard to determine if it is in danger or not. The system could show the passersby that it is installed and functioning through the built-in display inside of the car, for example showing the inside temperature.

The conclusion of the pre-study is that not all dogs or children are rescued by passersby who break the windows of the car. There will probably be cases where the HeatSafe system is installed and running, but passersby decide to break the windows because they want to help the child or dog anyway. The HeatSafe system is first of all installed in order to save lives of children and dogs in the case where nobody breaks the windows and takes action, and not to make sure that the parent or dog owner is fully comfortable with leaving the child or dog. So there is a risk that there will be unnecessary interferences with passersby, but this disadvantage with the system is outweighed by the advantage of more lives being saved by the system.

Dogs and children that are left alone in cars may not only suffer from hyperthermia, but other factors may contribute to them feeling uncomfortable as well. Children should not be left alone in cars at all. There is a risk that people will react when seeing a child or dog left alone in a car. The HeatSafe system makes sure that the child or dog does not suffer from hyperthermia, but the decision to leave the child or dog unattended and for how long lies within the responsibility of the parent or dog owner. It is natural that passersby may react if they see a child or dog left unattended regardless of heat. These consequences are part of the responsibilities as a caregiver or dog owner. People will probably continue to take action when finding dogs or children left alone in cars.

9.4 Suggestions for further development

Before implementing the HeatSafe system in cars, further development and studies are needed. A list of suggestions is presented below:

- Studies on temperatures in cars, regarding danger and timing for system actions.
- Studies on infrared cameras with proper field of view installed in car to verify selected cameras.
- Evaluation of the power required to power the selected infrared camera in relation to hybrid car battery capacity.
- Investigating the suggested placement of cameras with respect to potential obstacles.
- Verifying camera requirements (such as humidity resistance) according to circumstances in car.
- Studies on infrared camera software for optimising measure range.
- Cost estimations based on accurate data of volumes with infrared camera manufacturers.
- Development of reference images for camera software.
- Development of software to control system including software functionality for proper utilisation of camera, thermometer and additional information provided.
- Future development of infrared cameras with field of view up to 130 degrees.
- Investigating legal issues of automatically starting the AC in cars, and investigating emissions from cars with petrol or diesel engines.
- Thermodynamical calculation to determine proper level of cooling from AC.
- Testing of application and system with real parents and dog owners to investigate behaviour.
- Further development of sound and vibration for notifications from application.
- Further development and adjustments of application for android interface.
- Studies of behaviours of more risk taking parents and dog owners.

9.4.1 Other applications of infrared cameras in system

Implementing infrared cameras in cars in order to detect children or dogs will be expensive. In order to increase the value of the system the cameras could be utilised for other purposes inside of the car. Some suggestions are presented below:

- Medical detection of stroke
- Medical detection of fever
- Detection of driver falling asleep
- Detecting unwanted intruders inside of car
- Automatically adjusting climate system depending on passenger body temperature

10
Conclusion

During the study the goals of the project - investigating the problem and creating a feasible concept have been fulfilled. The problems related to children and dogs being left in cars that get hot has been described, and as a conclusion it has been noted that people generally seem to be aware of the risks with cars that get hot, including heatstroke, but there is a lack of understanding of how fast the car can heat up. Also people try to solve the problem with insufficient solutions, such as lowering the car windows, not being aware that these do not work. Veterinarians and paediatricians try to inform people on the risks but this does not seem to be sufficient to change the situation. There is a need of a solution not depending on human behaviour but rather being automated in order to solve the problem.

Currently there exists products on the market aiming at solving the problem, but all depending either on human interaction during use, or on a decision to buy the product separate from the car. In the project a new product concept "HeatSafe" different from the existing ones has been developed. HeatSafe is a system solution being integrated in the car, solving the problem with less reliance on the user's behaviour. This concept involves infrared cameras, the car software, the AC and a mobile application.

Some parts of the system are in need of more investigation before a system implementation, the software needs to be developed, and the infrared cameras with the desired properties need to be manufactured. In the current situation the suggestion is to focus the implementation of the system on hybrid vehicles, that do not generate emissions when starting the AC. More research is needed on legal issues with having the AC start automatically. When implementing new safety features there is a risk of users adjusting their behaviour according to the perceived lower risks. In the system the relevant information to the user has been presented as warnings rather than plain information, but further studies on behaviour could be needed.

It can be concluded that there is a possibility to implement the system in cars in the future that eliminates serious hyperthermia cases. The HeatSafe concept uses technology that is feasible today, and infrared technology with sufficient properties exists. However, this technology is expensive, and a desire for larger field of view of the infrared cameras remains. With full scale implementation and future development, the prices are likely to be feasible as well. So in a future situation the system could be implemented in cars.

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Appendix

A Interview guide veterinarians

General questions

- Would it be ok if we recorded the interview, instead of writing down notes?
- Do you wish to be anonymous or would it be fine if we use your name in the report?
- How long have you worked as a veterinarian?
- Do veterinarians have any specializations? Dogs? Hyperthermia?
- Do you have any specialization?

Hyperthermia in general

- Have you ever had a patient (dog) suffering from hyperthermia?
- How is hyperthermia usually treated?
- What factors contribute to hyperthermia? How long time does it take for it to occur?
- What are the usual consequences of hyperthermia? Do the dog recover quickly, is it possible for dogs to die or suffer from any serious damage, permanent?
- Are different breeds affected in different way by heat?
- What attributes affect the hyperthermia, size of the dog, the fur, the age?

Hyperthermia and car use

- Do you have any perception on how common it is for dogs to suffer from hyperthermia due to being left in a car?
- Does the space the dog is located in affect the risk of hyperthermia? Will a small car be more dangerous? Will heat and air and humidity affect?
- Does the ability to move affect the risk of hyperthermia? If the dog is placed in a cage, belted or loose?
- People tend to use different precautions to prevent dogs from suffering from hyperthermia, what is your opinion on them? (Lowering the windows, putting the car in shade etc.) Do you have examples of more precautions usually taken?
- What precautions do actually work to prevent hyperthermia?
- What can be done when a dog is suffering from hyperthermia in a car if you are a person detecting it? Treatments at the spot?

Final questions

- Do you know about someone that we should interview further on the subject? Any specialist?
- Do you have any litterature tips on the subject that could be of interest?
- Do you have any final comments on the subject?

B Interview guide physicians

General questions

- Would it be ok if we recorded the interview, instead of writing down notes?
- Do you wish to be anonymous or would it be fine if we use your name in the report?
- How long have you worked as a physician?
- Do you have any specialization?

Hyperthermia in general

- Have you ever had a patient (child) suffering from hyperthermia?
- How is hyperthermia usually treated?
- What factors contribute to hyperthermia? How long time does it take for it to occur?
- What are the usual consequences of hyperthermia? Do the child recover quickly, is it possible for children to die or suffer from any serious damage, permanent?
- Are children of different age affected in different way by heat?

Hyperthermia and car use

- Do you have any perception on how common it is for children to suffer from hyperthermia due to being left in a car?
- Does the space the child is located in affect the risk of hyperthermia? Will a small car be more dangerous? Will heat and air and humidity affect?
- At what age is it safe to leave a child in a car? at what age will the child be able to get out by itself or at what age is it not affected as much by heat?
- Does the ability to move affect the risk of hyperthermia? If the child is placed in a car safety seat or direct on the regular seat? If the child is belted or not?
- People tend to use different precautions to prevent children from suffering from hyperthermia, what is your opinion on them? (Lowering the windows, putting the car in shade etc.) Do you have examples of more precautions usually taken?
- What precautions do actually work to prevent hyperthermia?
- What can be done when a child is suffering from hyperthermia in a car if you are a person detecting it? Treatments at the spot?

Final questions

- Do you know about someone that we should interview further on the subject? Any specialist?
- Do you have any litterature tips on the subject that could be of interest?
- Do you have any final comments on the subject?

C Interview guide parents/dog owners

About you

- How old are you?
- How many children do you have?
- How old are they?
- How many dogs do you have?
- For how long time have you had a dog?
- What type of breed of dog have you owned?
- What type of car do you usually drive?

General questions

- Why do you think children/dogs are left alone in a car? (Stress?)
- How do you think the personality of the dog/child affects the situation? For example an aggressive dog?

Questions about leaving dog/child in car

- In which situations do you bring your dog/child with you in the car?
- How is the dog/child placed in the car?
- Have you ever left your dog/child in a car alone on purpose?
- Why are you leaving it alone in the car? In which situations?
- Do you consider the time it is left in the car?
- How do you consider the age of the child/dog, is there an age by which it feels okay to leave it alone?
- Have you ever forgotten your dog/child in a car?

Possible scenario

- You are on your way by car to a shopping mall in order to make some errands. You have your dog/child with you in the car. When you have parked you car you decide to leave your dog/child in the car alone.
- What do you do during this situation, starting with your arrival to the shopping mall all the way until you departure from it?
- Do you consider how you are leaving it alone in the car? Do you consider the placement of the dog/child in the car? What season it is? What time it is during the day?
- How do you consider the temperature outside?
- Do you consider the safety? Do you make any arrangements when you leave it in the car alone?
- Problems with unlocked car? Open windows?

Risks

- Do you get any information about what rules and regulations to consider when leaving your dog/child in a car alone?
- Are you aware of any risks with leaving your dog/child in a car alone? (Heat)
- What would you do if you saw a dog/child in a car alone that seemed affected by the heat?
- At what situation would you feel the need to do something?

Products

- Do you know about any products supposed to help with the problem with dogs and children in hot cars?
- What do you think about using a separate product that will prevent you from forgetting you dog/child in the car alone?
- What do you think about using a separate product that will alarm you if it gets too hot in the car?

D Questionnaire dog

Default Question Block

Hej!

Vi är två studenter som skriver vårt examensarbete på Chalmers Tekniska Högskola. Med denna enkät vill vi få bättre förståelse kring hur människor tänker på att lämna hundar i bilar. Alla svar kommer att behandlas anonymt.

Tack för att du tar dig tid!

Hur gammal är du (år)?

- ○ 18-24
- ○ 25-29
- ○ 30-39
- ○ 40-49
- ○ 50-59
- ○ 60-69
- ○ 70-79
- ○ 80+

Kön?

- ○ Man
- ○ Kvinna
- ○ Varken man eller kvinna

Hur många hundar har du?

0 1 2 3 4 5 6 7 8 9 10

Antal

Vilken/vilka typer av bil(ar) kör du?

- ☐ Kombi
- ☐ Sedan
- ☐ Coupé
- ☐ Cabriolet
- ☐ Stadsjeep/SUV
- ☐ Minibuss
- ☐ Skåpbil
- ☐ Kör inte bil

Kör du en Volvo?

- ○ Ja
- ○ Nej

Har du lämnat en hund med flit i en bil ensam någon gång?

- ○ Ja, ofta
- ○ Ja, ibland
- ○ Nej, aldrig

Vad för sorts hund brukar du lämna kvar i bilen?

- ○ Trubbnosig (ex. mops eller bulldog)
- ○ Icke trubbnosig
- ○ Både trubbnosiga och icke trubbnosiga (flera hundar)

Har du glömt en hund i en bil ensam någon gång?

- ○ Ja, ofta
- ○ Ja, ibland
- ○ Nej, aldrig

Vad för sorts hund brukar du glömma kvar i bilen?

- ○ Trubbnosig (ex. mops eller bulldog)
- ○ Icke trubbnosig
- ○ Både trubbnosiga och icke trubbnosiga (flera hundar)

Uppskatta hur länge du brukar lämna/glömma hunden ensam? Ange eventuellt fler svar.

- ☐ Ca 15 min
- ☐ Ca 30 min
- ☐ Ca 1 timme
- ☐ Ca 2 timmar
- ☐ Ca 3 timmar
- ☐ Mer än 3 timmar
- ☐ Minns ej

Under vilken/vilka årstider lämnade du hunden ensam i bilen?

- ☐ Vår
- ☐ Sommar
- ☐ Höst
- ☐ Vinter
- ☐ Minns ej

Vilka av dessa säkerhetsåtgärder har du vidtagit vid lämnandet, och hur ofta?

	Alltid	Ibland	Aldrig
Vevat ner rutan	○	○	○
Ställt bil i skugga	○	○	○
Öppnat bagageluckan	○	○	○
Annat	○	○	○

Hur har du placerat hunden när det varit lämnat? Ange eventuellt fler svar.

- ☐ I bur
- ☐ Bältad i sele
- ☐ Lös
- ☐ Annat
- ☐ Minns ej

Har du sett någon hund lämnat ensamt i en bil?

- ○ Ja, ofta
- ○ Ja, ibland
- ○ Nej, aldrig

Vad för sorts hund har du sett vara lämnad kvar i en bil?

- ○ Trubbnosig (ex. mops eller bulldog)
- ○ Icke trubbnosig
- ○ Både trubbnosiga och icke trubbnosiga (flera hundar)
- ○ Minns ej

Under vilken/vilka årstider såg du hunden bli lämnad ensam i bilen?

- ☐ Vår
- ☐ Sommar
- ☐ Höst
- ☐ Vinter
- ☐ Minns ej

När du sett en hund blivit lämnat i en bil, hur ofta har du sett följande säkerhetsåtgärd?

	Alltid	Ibland	Aldrig
Vevat ner rutan	○	○	○
Ställt bil i skugga	○	○	○
Öppnat bagageluckan	○	○	○
Annat	○	○	○

Hur var hunden placerat när du såg det varit lämnat? Ange eventuellt fler svar.

- ☐ I bur
- ☐ Bältad i sele
- ☐ Lös
- ☐ Annat
- ☐ Minns ej

Är du medveten om hur varm en bil kan bli under en varm dag på kort tid?

- ○ Ja
- ○ Till viss del
- ○ Nej

Är du medveten om riskerna med att hundar kan drabbas av värmeslag då de lämnas kvar i en varm bil?

- ○ Ja
- ○ Till viss del
- ○ Nej

Har du läst eller hört om fall där hundar har drabbats av värmeslag i bil?

- ○ Ja
- ○ Nej

Skulle du kunna tänka dig köpa en separat produkt som förhindrar att hundar drabbas av värmeslag i bil?

- ○ Ja
- ○ Nej

Skulle du kunna tänka dig att köpa en bil med inbyggt system som förhindrar att hundar drabbas av värmeslag i bil?

- ○ Ja
- ○ Nej

Har du några övriga tankar om ämnet som vi missade att fråga om?

E Questionnaire child

Default Question Block

Hej!

Vi är två studenter som skriver vårt examensarbete på Chalmers Tekniska Högskola. Med denna enkät vill vi få bättre förståelse kring hur människor tänker på att lämna barn mellan 0-6 år i bilar. Alla svar kommer att behandlas anonymt.

Tack för att du tar dig tid!

Hur gammal är du (år)?

- 18-24
- 25-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70-79
- 80+

Kön?

- Man
- Kvinna
- Varken man eller kvinna

Hur många barn har du?

0 1 2 3 4 5 6 7 8 9 10

Antal

Vilken/vilka typer av bil(ar) kör du?

- ☐ Kombi
- ☐ Sedan
- ☐ Coupé
- ☐ Cabriolet
- ☐ Stadsjeep/SUV
- ☐ Minibuss
- ☐ Skåpbil
- ☐ Kör inte bil

Kör du en Volvo?

- ○ Ja
- ○ Nej

Har du lämnat ett barn ensamt med flit i en bil någon gång?

- ○ Ja, ofta
- ○ Ja, ibland
- ○ Nej, aldrig

Har du glömt ett barn ensamt i en bil någon gång?

- ○ Ja, ofta
- ○ Ja, ibland
- ○ Nej, aldrig

Hur gammalt har barnet varit när du har lämnat/glömt det? Ange eventuellt fler svar.

- ☐ Mindre än 1 år
- ☐ 1-2 år
- ☐ 3-4 år
- ☐ 5-6 år
- ☐ 6+ år

När barnet var mindre än 1 år, hur länge lämnade/glömde du det ensamt? Ange eventuellt fler svar.

- ☐ Ca 15 min
- ☐ Ca 30 min
- ☐ Ca 1 timme
- ☐ Ca 2 timmar
- ☐ Ca 3 timmar
- ☐ Mer än 3 timmar
- ☐ Minns ej

När barnet var mindre än 1 år, vid vilken/vilka årstider lämnade/glömde du det ensamt?

- ☐ Vår
- ☐ Sommar
- ☐ Höst
- ☐ Vinter
- ☐ Minns ej

När barnet var 1-2 år, hur länge lämnade/glömde du det ensamt? Ange eventuellt fler svar.

- [ ] Ca 15 min
- [ ] Ca 30 min
- [ ] Ca 1 timme
- [ ] Ca 2 timmar
- [ ] Ca 3 timmar
- [ ] Mer än 3 timmar
- [ ] Minns ej

När barnet var 1-2 år, vid vilken/vilka årstider lämnade/glömde du det ensamt?

- [ ] Vår
- [ ] Sommar
- [ ] Höst
- [ ] Vinter
- [ ] Minns ej

När barnet var 3-4 år, hur länge lämnade/glömde du det ensamt? Ange eventuellt fler svar.

- [ ] Ca 15 min
- [ ] Ca 30 min
- [ ] Ca 1 timme
- [ ] Ca 2 timmar
- [ ] Ca 3 timmar
- [ ] Mer än 3 timmar
- [ ] Minns ej

När barnet var 3-4 år, vid vilken/vilka årstider lämnade/glömde du det ensamt?

- [ ] Vår
- [ ] Sommar
- [ ] Höst

- [ ] Vinter
- [ ] Minns ej

När barnet var 5-6 år, hur länge lämnade/glömde du det ensamt? Ange eventuellt fler svar.

- [ ] Ca 15 min
- [ ] Ca 30 min
- [ ] Ca 1 timme
- [ ] Ca 2 timmar
- [ ] Ca 3 timmar
- [ ] Mer än 3 timmar
- [ ] Minns ej

När barnet var 5-6 år, vid vilken/vilka årstider lämnade/glömde du det ensamt?

- [ ] Vår
- [ ] Sommar
- [ ] Höst
- [ ] Vinter
- [ ] Minns ej

När barnet äldre än 6 år, hur länge lämnade/glömde du det ensamt? Ange eventuellt fler svar.

- [ ] Ca 15 min
- [ ] Ca 30 min
- [ ] Ca 1 timme
- [ ] Ca 2 timmar
- [ ] Ca 3 timmar
- [ ] Mer än 3 timmar
- [ ] Minns ej

När barnet var äldre än 6 år, vid vilken/vilka årstider lämnade/glömde du det ensamt?

- ☐ Vår
- ☐ Sommar
- ☐ Höst
- ☐ Vinter
- ☐ Minns ej

Vilka av dessa säkerhetsåtgärder har du vidtagit vid lämnandet, och hur ofta?

	Alltid	Ibland	Aldrig
Vevat ner rutan	○	○	○
Ställt bil i skugga	○	○	○
Babymonitor	○	○	○
Annat	○	○	○

Hur har du placerat barnet när det varit lämnat? Ange eventuellt fler svar.

- ☐ I babyskydd
- ☐ I bilbarnstol
- ☐ I bältesstol
- ☐ På kudde
- ☐ Direkt på sätet
- ☐ Minns ej

Var barnet fastspänt med säkerhetsbälte när du lämnade det?

- ○ Ja alltid
- ○ Ibland
- ○ Nej aldrig

- ○ Minns ej

Har du sett något barn lämnat ensamt i en bil?

- ○ Ja, ofta
- ○ Ja, ibland
- ○ Nej, aldrig

Hur gammalt har barnet du sett varit? Ange eventuellt fler svar.

- ☐ Mindre än 1 år
- ☐ 1-2 år
- ☐ 3-4 år
- ☐ 5-6 år
- ☐ 6+ år
- ☐ Minns ej

Vid vilken/vilka årstider såg du barnet vara lämnat?

- ☐ Vår
- ☐ Sommar
- ☐ Höst
- ☐ Vinter
- ☐ Minns ej

När du sett ett barn lämnat i en bil, hur ofta har du sett följande säkerhetsåtgärd?

	Alltid	Ibland	Aldrig
Vevat ner rutan	○	○	○
Ställt bil i skugga	○	○	○
Babymonitor	○	○	○
Annat	○	○	○

Hur var barnet placerat när du såg det varit lämnat? Ange eventuellt fler svar.

- ☐ I babyskydd
- ☐ I bilbarnstol
- ☐ I bästesstol
- ☐ På kudde
- ☐ Direkt på sätet
- ☐ Minns ej

Var barnet fastspänt med säkerhetsbälte när du såg det lämnat?

- ○ Ja alltid
- ○ Ja ibland
- ○ Nej aldrig
- ○ Minns ej

Är du medveten om hur varm en bil kan bli under en varm dag på kort tid?

- ○ Ja
- ○ Tillviss del
- ○ Nej

Är du medveten om riskerna med att barn kan drabbas av värmeslag då de lämnas kvar i en varm bil?

- ○ Ja
- ○ Tillviss del
- ○ Nej

Har du läst eller hört om fall där barn har drabbats av värmeslag i bil?

- ○ Ja
- ○ Nej

Skulle du kunna tänka dig köpa en separat produkt som förhindrar att barn drabbas av värmeslag i bil?

- ○ Ja
- ○ Nej

Skulle du kunna tänka dig att köpa en bil med inbyggt system som förhindrar att barn drabbas av värmeslag i bil?

- ○ Ja
- ○ Nej

Har du några övriga tankar om ämnet som vi missade att fråga om?

F Questionnaire distribution channels

Dog forums

- http://www.hundpunkten.se/hundforum.aspx
- http://hundar.ifokus.se/
- https://vovve.net/Rastplatsen/Hundforum.asp
- http://www.bukefalos.com/forums/hund.55/

Parent forums

- http://www.viforaldrar.se/forum
- http://www.alltforforaldrar.se/
- http://www.familjeliv.se/
- http://vimedbarn.se/forum/
- http://www.mammapappa.com/forum/

Elderly dog owners

- http://www.viseniorer.se/forum/

G Benchmark products

Product name	Bee-alert	iRemind car seat alarm	Driver's little helper
Market	Child	Child	Child
Type of product	Alarm leave	Alarm leave	Alarm leave/alarm hot and cold/alarm arrival
Price	19.95$	99.99$	79.99$
Utilises mobile application?	No	Yes, compulsory	Yes
Functionality	When the car door is opened the alarm says "child alert, check car seat".	Audible and visual notification if you walk away from car leaving child in seat.	Audible and visual notification in the users mobile phone, checking the temperature, movement and the arrival.
Technical details	An alarm that is placed inside a car door	Soft pad with electronical device measuring weight.	Sensor under the car seat's fabric, power pack attached to the sensor and app synchronised to the driver's little helper.
Retailer (link)	http://www.bee-alert.com/	http://www.sunshine babyalarm.com/	http://drivers littlehelper.com/

Product name	R.O.L.O - Remember our little ones	Halo Baby seat safety system	Halo Pet safety system
Market	Child/dog	Child	Dog
Type of product	Other	Alarm leave/alarm hot	Alarm hot
Price	Free	149$	69$
Utilises mobile application?	No	Yes	Yes
Functionality	Reminder by sticker placed inside car, both to remind you and fellow people.	If driver exits vehicle without baby the alarm will sound on phone and key pod. Second alarm if the car gets too hot.	If temperature gets too high the phone or key pod unit alarms you
Technical details	Sticker.	Seat pad under seat and base unit on side of car seat. Heat and weight monitor.	Proximity sensor on pet collar, base unit in vehicle, when proximity sensor near base unit it activates and monitors temperature in car.
Retailer (link)	https://www.crestcadillactx.com/june/remember-our-little-ones.htm	http://sistersofinvention.com/	http://sistersofinvention.com/

Product name	Kars4kids	NASA Child presence sensor	Evenflo Advanced Sensorsafe™ Embrace Dlx Infant Car Seat
Market	Child	Child	Child
Type of product	Alarm leave	Alarm leave	Alarm arrival
Price	Free	20-30$	150$
Utilises mobile application?	Yes	No	No
Functionality	The alarm goes off when you and your phone leave the car.	Alarm on key ring alerts driver if he or she moves too far from vehicle, stops when driver returns to child seat.	Upon arrival at your destination it will generate a series of tones, reminding you that your baby is present in the vehicle.
Technical details	App with several different features.	Sensor switch that triggers if a child is placed in the seat, sensitivity of eight ounces. Transmits code via radio-frequency link.	A child safety seat with a chest clip that generate series of tones and a receiver that notifies the user.
Retailer (link)	http://www.kars4kids.org/safety-app/	Not available	http://www.evenflo.com

Product name	AnimAlarm	AniMat cool gel mat
Market	Dog	Dog
Type of product	Alarm hot	Cooling
Price	99£	24.99-64.99£
Utilizes mobile application?	Yes	No
Functionality	Alerts your phone with text message when critical temparutre is reached.	Mat that cools your dog for hours.
Technical details	Sensor that senses temperature in car, uses GSM network to send text to phone.	Contains cooling gel, no activation needed.
Retailer (link)	http://theanimalarm.com	http://theanimalarm.com

Product name	Silver Shade Cooler	Hot dog temperature alert
Market	Dog	Dog
Type of product	Cooling	Other
Price	15.20-29.00£	2.33$
Utilizes mobile application?	No	No
Functionality	Dog coat that prevents your dog from getting hot.	Shows temperature inside of the car.
Technical details	Reflective surface that reflects away heat.	Regular thermometer showing the temperature inside the car.
Retailer (link)	http://theanimalarm.com	http://www.amazon.co.uk/Hot-Alert-Interior-Warning-Pets/dp/B002DKVK6S

H Benchmark patents

Patent name	Body Temperature Warning System	Vehicle having a thermal protection arrangement for toddlers and pets	Occupant detection and temperature forewarn safety system and method
Market	Child/dog	Child/dog	Child/dog
Type of product	Alarm hot	Alarm hot/cooling	Alarm hot
Patent number	US20140266694A1	US6263272B1	US20070013531A1
Utilizes mobile application?	Not specified	Not specified	No
Functionality	Warns user if child or pet becomes too hot in car.	Opens the windows and sunroof when the car gets too hot and also alarms the user.	When it becomes too hot in the car and if a person/animal is inside the car alerts the surrounding by flashing lights, honking, noticing the driver by a device and lowering windows.
Technical details	Monitoring device that senses that a child/dog is present, Werable body sensor that measures the body teperature.	Uses a temperature sensor that communicates with a vehicle micro controller that sends signals to the windows and the sunroof of the car.	Temperature sensor + occupant sensor and antenna. Connects to the host security system utilizing car horn etc.

Patent name	Wireless car seat locator and child safety occupancy alert system	Back seat passenger reminder device	Life-saving child car seat/carrier system designed to protect against passenger compartment temperature extremes
Market	Child	Child/dog	Child
Type of product	Alarm leave	Alarm arrival	Alarm hot/cooling
Patent number	US20070279206A1	US20070220793A1	US20090277190A1
Utilizes mobile application?	No	No	No
Functionality	Alerts driver that a child is inside of the car through email or texts. Also usable for other applications than car.	A two sided planar surface that have a reminder message on one side and a cut out and/or a transparent area in which a picture can be inserted on the other side.	A child container that senses temperature and alarms driver via mobile phone, and surroundings via the car lights and horn, as well as cools the baby inside if temperature get too high. The container is both a car seat and a transportable carrier.
Technical details	Wireless device attached to car seat, alerts if the child has been in the car seat after a specified amount of time. Motion sensor on driver that alerts driver to remove child from car (when he/she leaves car and removes the seat belt).	A planar surface that can be attached with Velcro or suction-cup to some window.	A temperature sensor to sense the temperature, the container is thermally insulated and a thermoelectric device cools the child. Alarm system consisting of an auto dialing phone, and a system to control the car lights and horn.

Patent name	Hot vehicle safety system and methods of preventing passenger entrapment and heat suffocation	Car heatstroke-prevention alarm system based on Bluetooth network	System for Child Safety
Market	Child/dog	Child	Child
Type of product	Alarm hot	Alarm hot/other	Alarm arrival
Patent number	US20020161501A1	CN203455921U	US20100265055A1
Utilizes mobile application?	Not specified	No	No
Functionality	A system that senses the occupancy of a passenger and the temperature inside the car and provides interior and/or exterior warning of a trapped passenger. The outputs of the system can also activate other systems that relieve the heat by rolling down the window or, unlocking dors etcetera.	Senses that a person is inside car, the temperature and the amount of toxic gases and alerts the driver via a bluetooth device when levels get critical.	When the vehicle ignition is turned off and the child safety seat is engaged an alarm in the car goes of.
Technical details	Uses sensors that senses the occupancy of a passenger and a temperature sensor as well.	A bluetooth module, a processor and a prompting module make up the bluetooth system, inside of the car is a body sensor, temperature sensor and a gas concentration sensor.	Uses the internal wiring or the computer system of a vehicle in order to alert the driver.

Patent name	Dog shading screen	Child abandonment protection system
Market	Dog	Child
Type of product	Other/cooling	Alarm leave
Patent number	US9205723B2/ US20140174675A1	US20080119989A1
Utilizes mobile application?	No	Not specified
Functionality	A shading screen that provides shade and ventilation to the dog.	When a child have been unintentionally left in an unattended vehicle a signal is sent to the driver in order to alert him.
Technical details	The shading screen is placed in the rear opening of tha car and the rear is opened for ventilation.	Uses an electronic system installed in a vehicle and a sensor installed on a child safety seat, car seat or on vehicle itself.

Patent name	Dog cooling garment	Baby cord
Market	Dog	Child
Type of product	Cooling	Alarm leave
Patent number	US20050284416A1	US8120499B2
Utilizes mobile application?	No	No
Functionality	A cooling vest worn by the dog.	Alerts the driver when he or she leaves the car without a child.
Technical details	The vest is put in the fridge or freezer to get cold, and has an outer reflective surface to provide additional cooling.	A cord is placed between the driver and the car seat of the child with magnetic clips. When the magnets detach (when the driver leaves the car) a sound is played from the device to reming that the child is still in the car.

I Questionnaire results

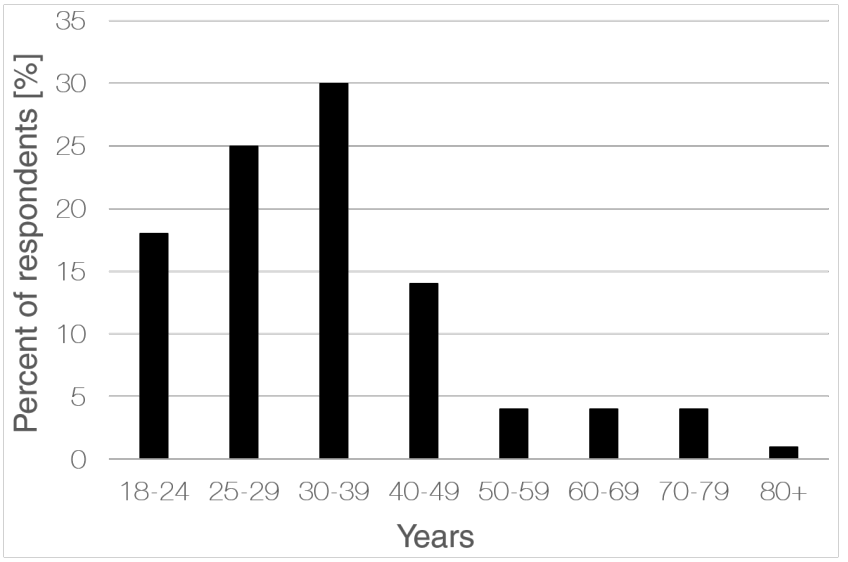


Figure A.1: Age of dog owners

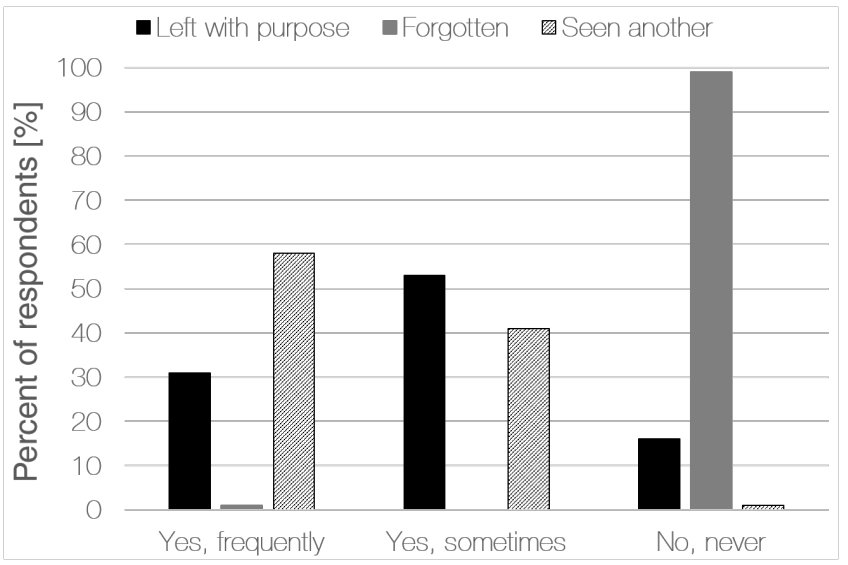


Figure A.2: Dogs being left in cars by different reasons

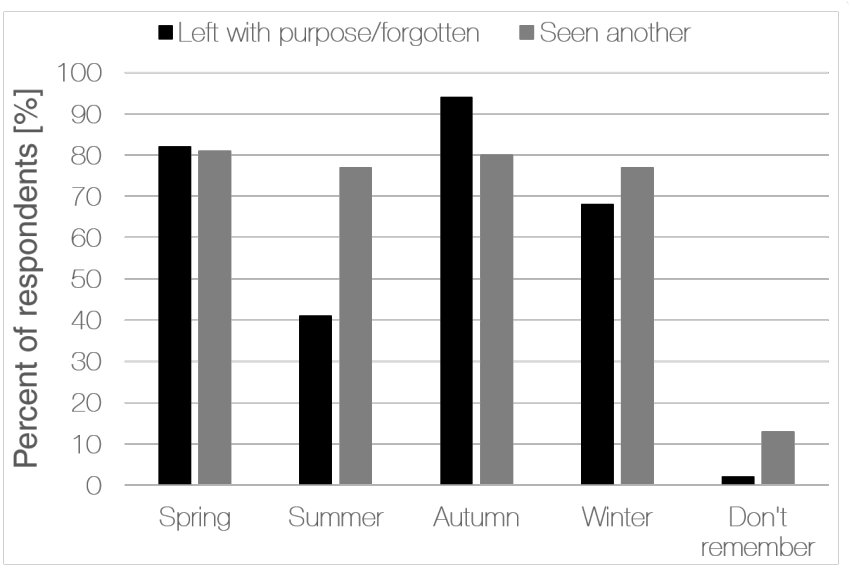


Figure A.3: Seasons during which dogs are left or seen left in cars

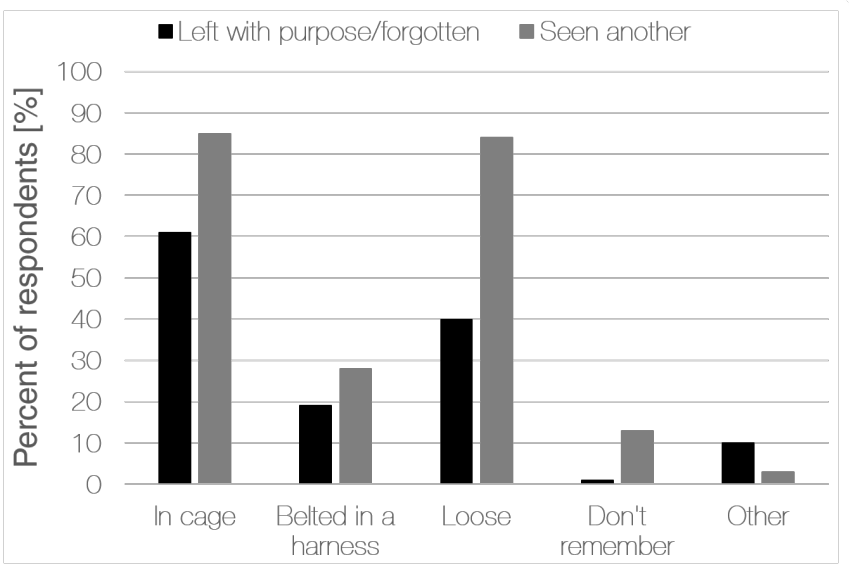


Figure A.4: Placement of dogs in cars

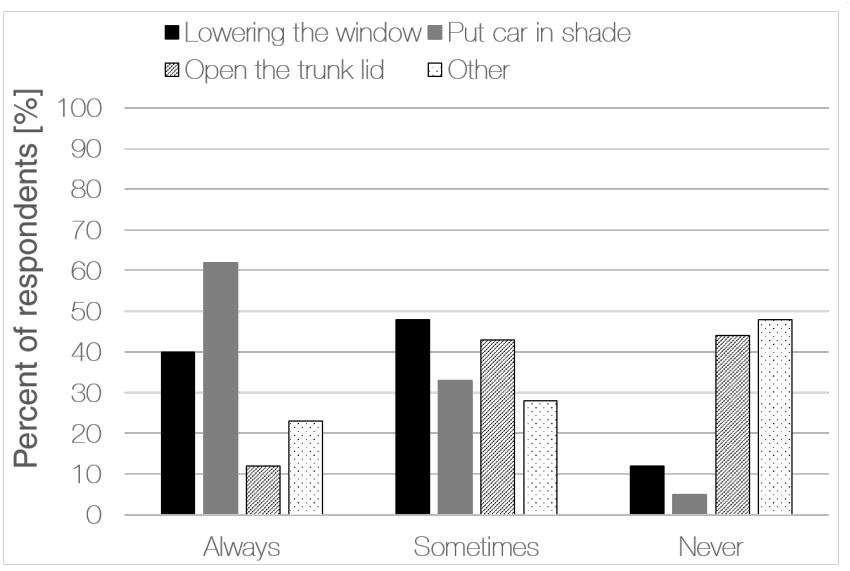


Figure A.5: Precautions taken when leaving dog in car

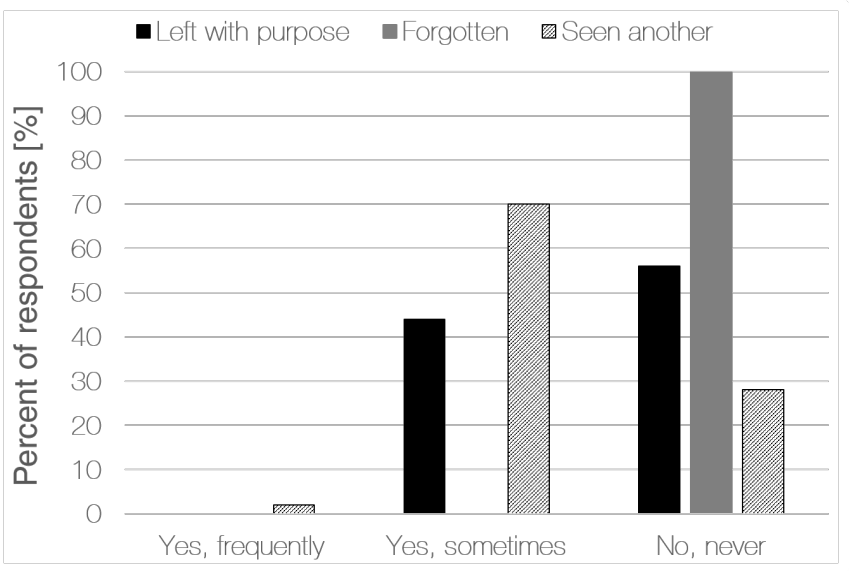


Figure A.6: Children being left in cars by different reasons

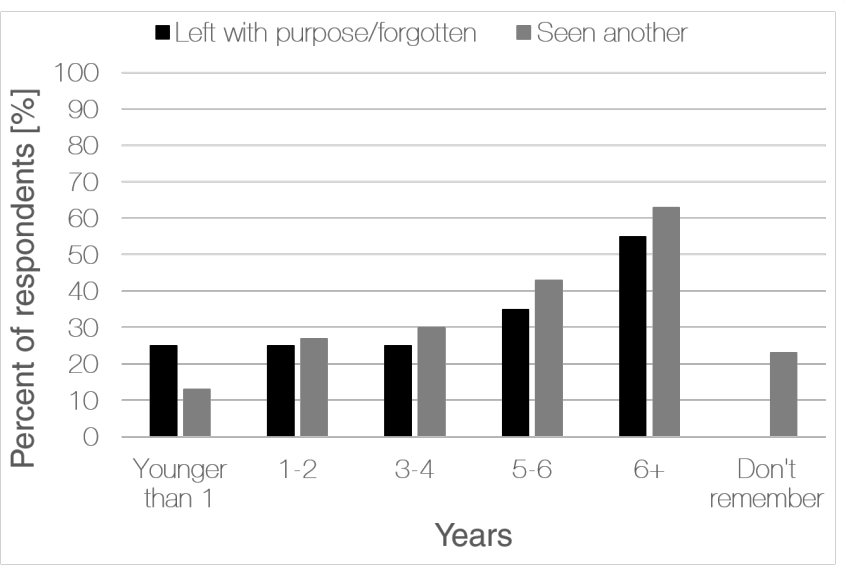


Figure A.7: Children being left in the car, different ages

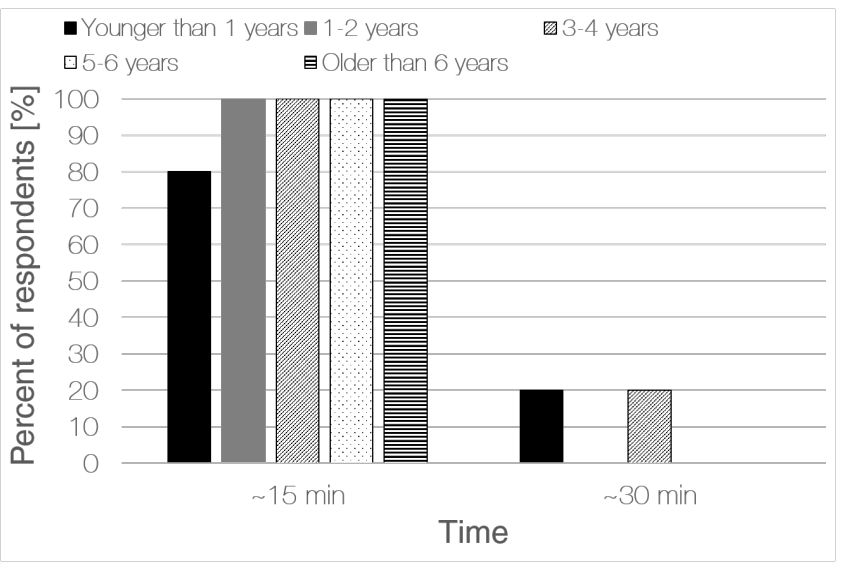


Figure A.8: Time being left in the car, children

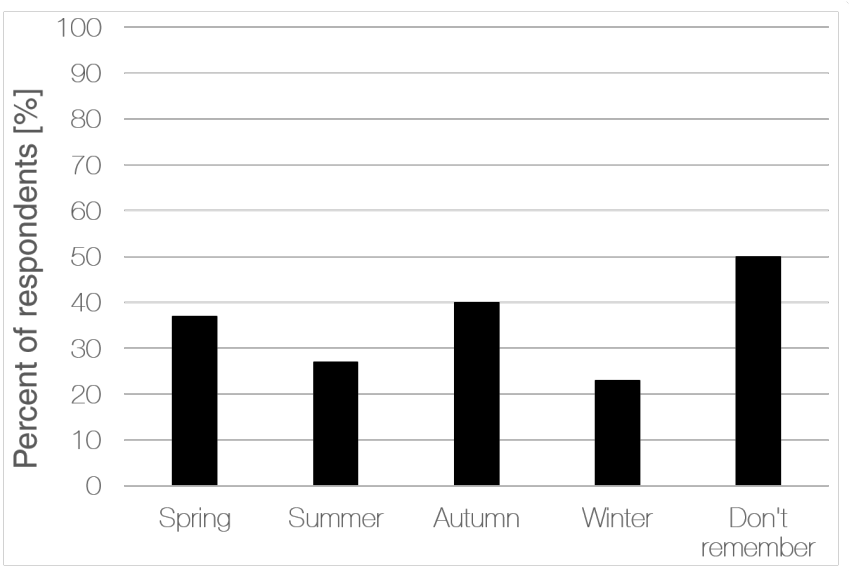


Figure A.9: Time of year of noticing other children being left in cars

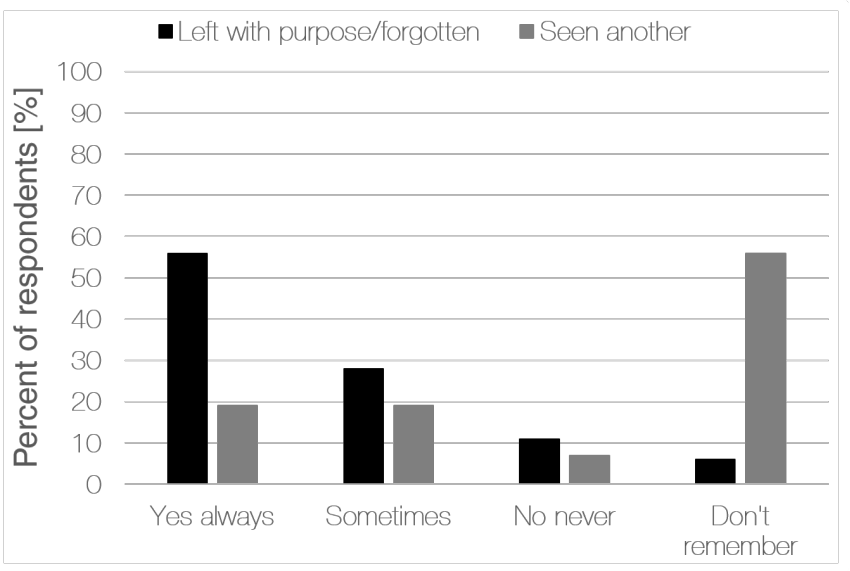


Figure A.10: Use of safety belt when leaving the child in a car

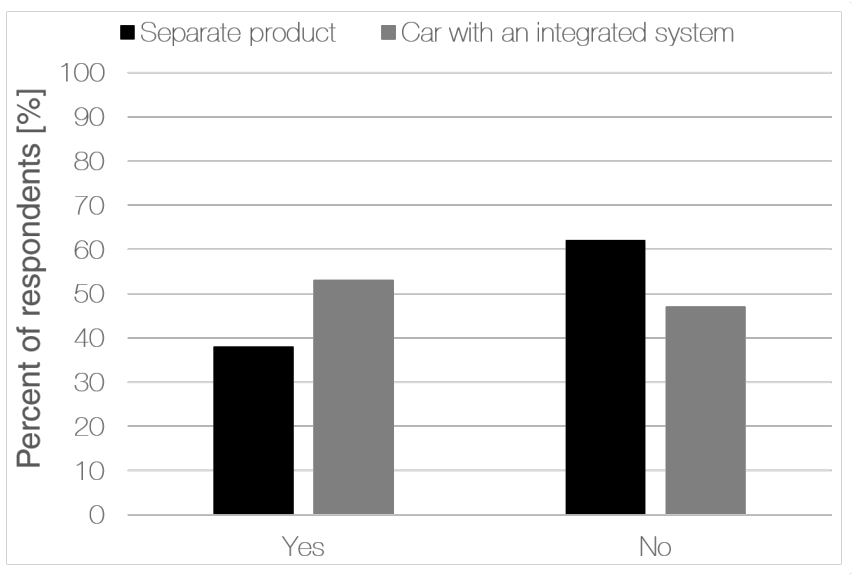
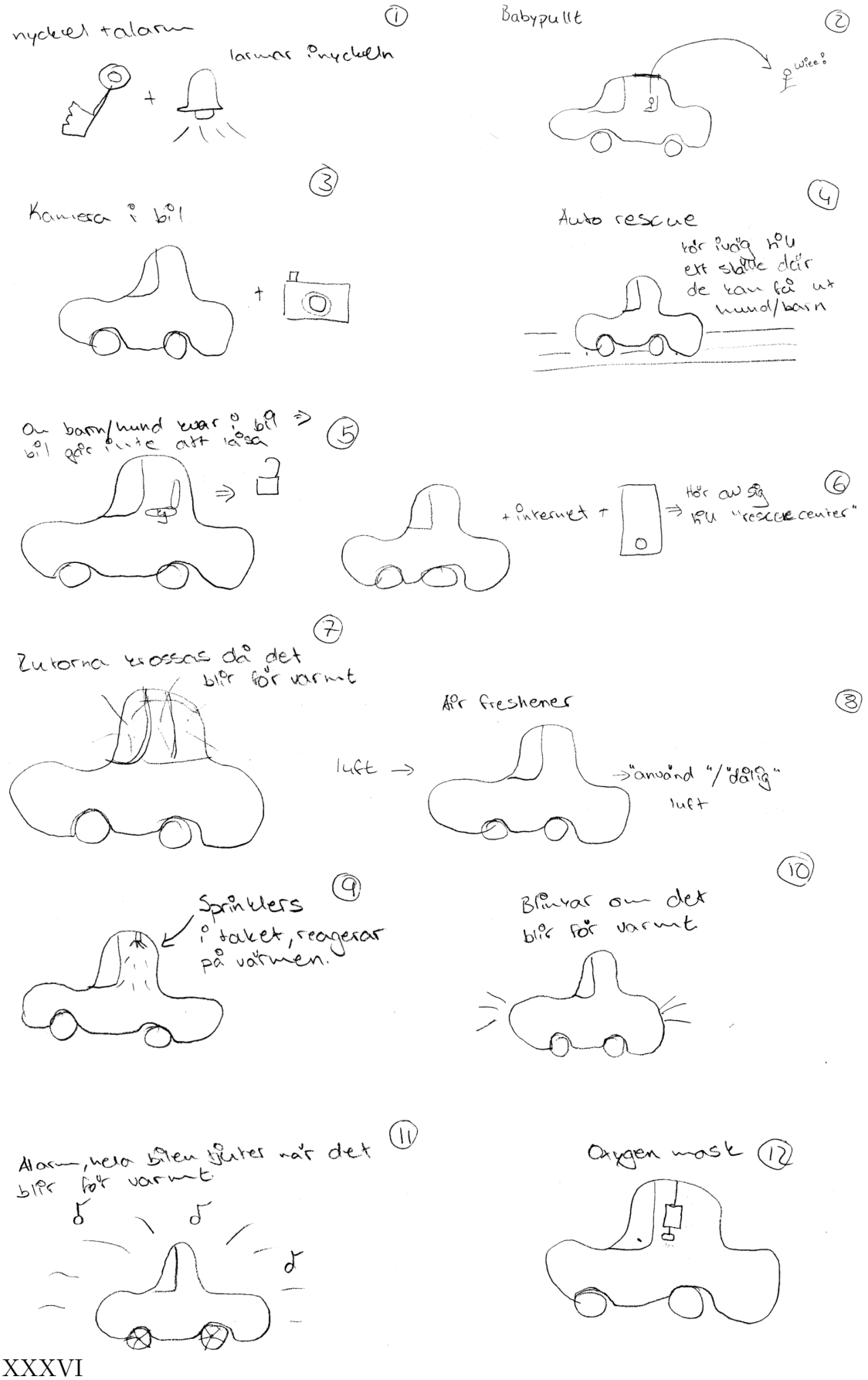
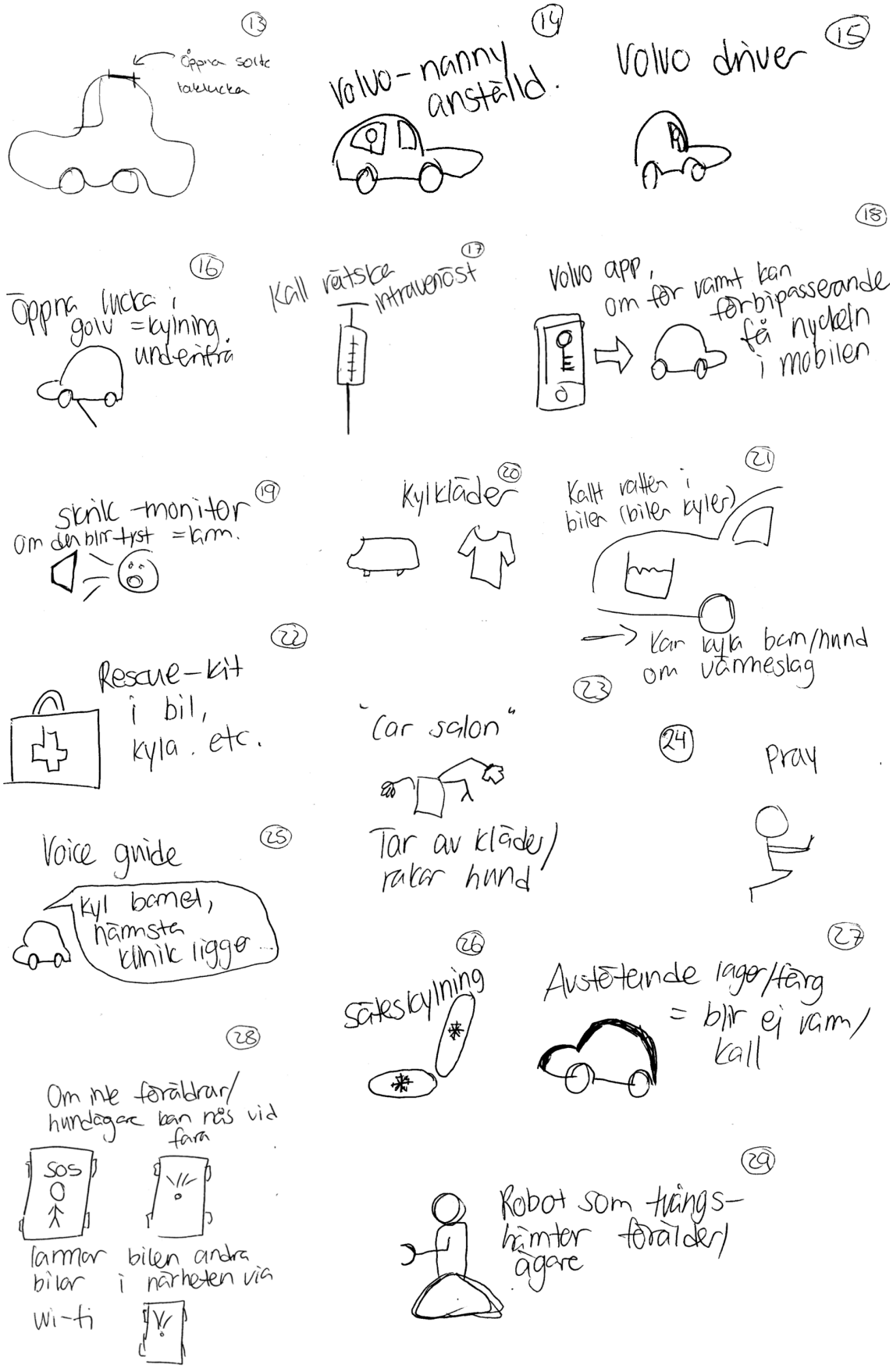


Figure A.11: Interest in future product, children

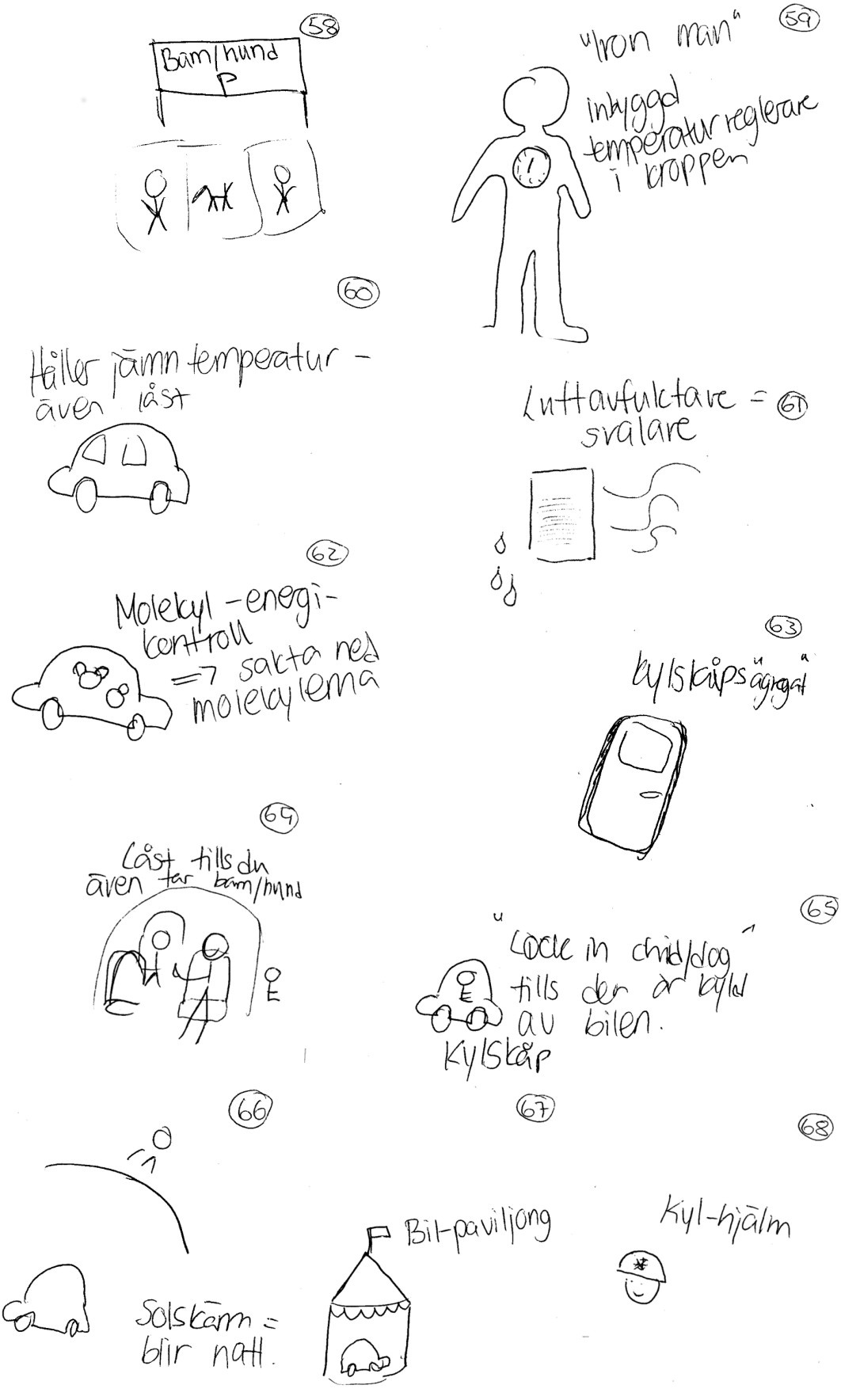
J Subsystem concepts

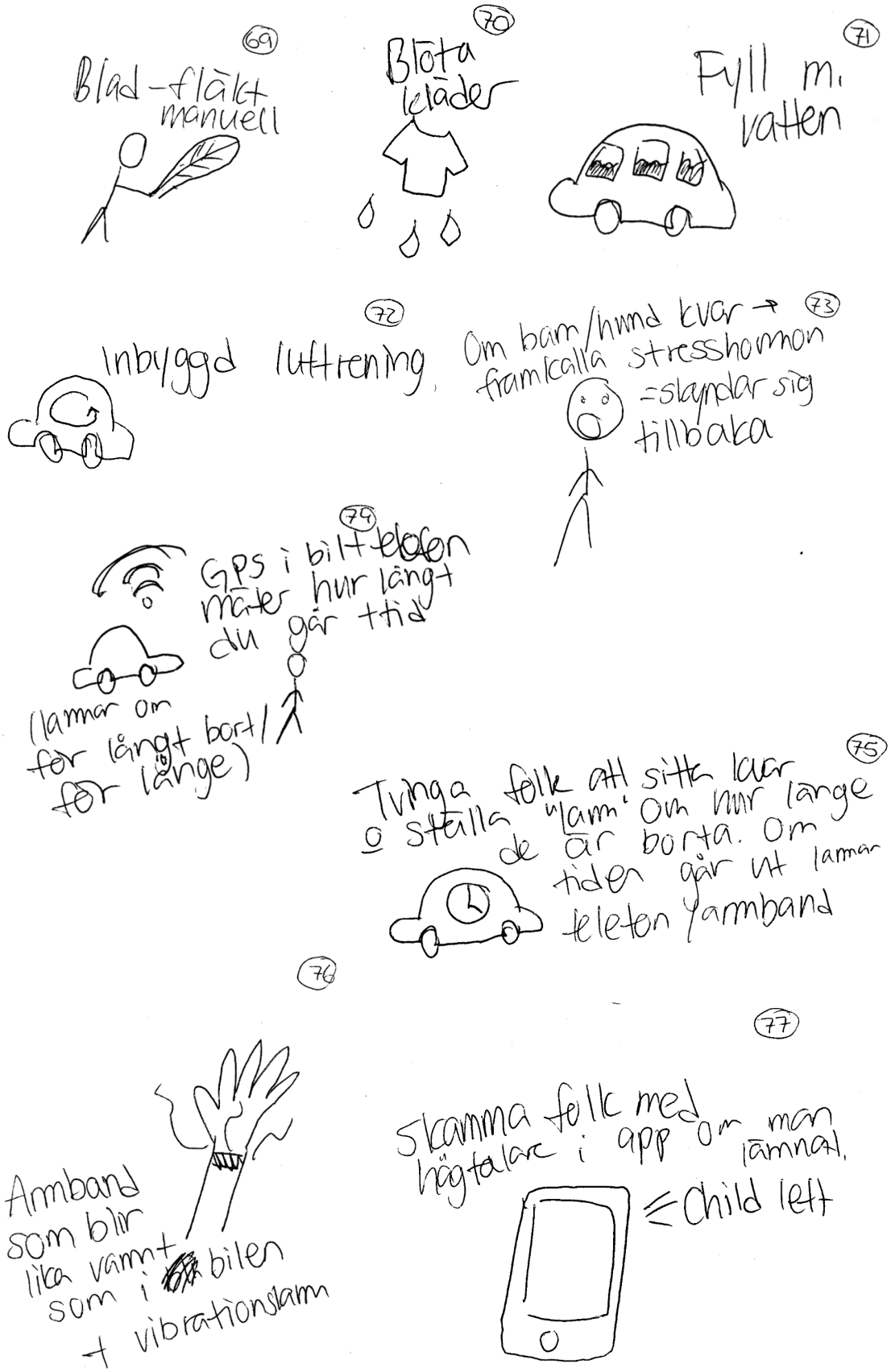


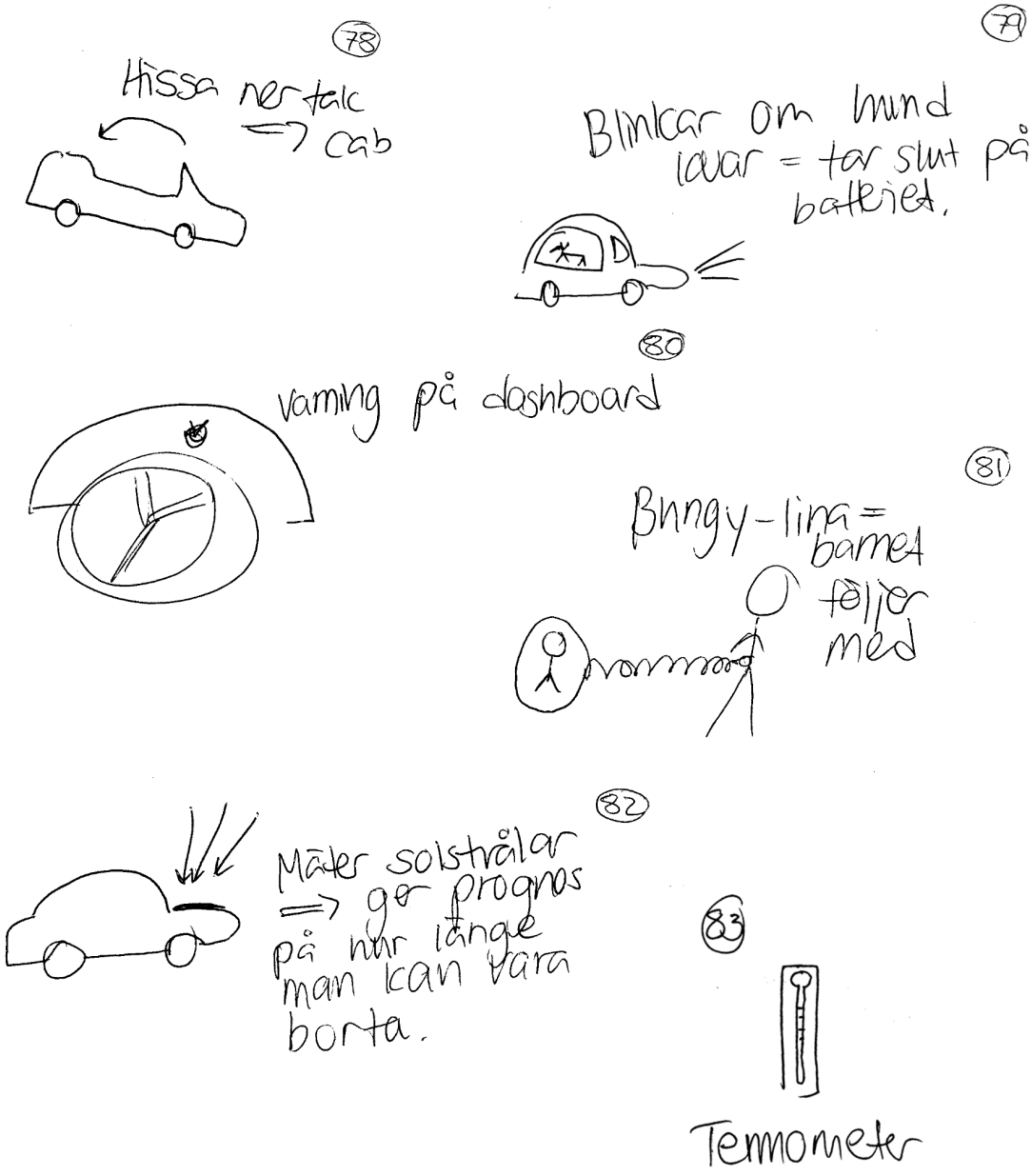

13
Öppna soltak takfönster
14
Volvo-nanny anställd.
15
Volvo driver
16
Öppna lucka i golv = kylning underifrån
17
Kall rätsida intravenöst
18
Volvo app, om för varmt kan förbipasserande få nyckeln i mobilen
19
Skrik monitor om den blir tyst = barn.
20
Kylkläder
21
Kallt vatten i bilen (bilen kyler)
Kan kyla barn/hund om värmeslag
22
Rescue-kit i bil, kyla, etc.
23
"Car salon"
Tar av kläder/ rakar hund
24
Pray
25
Voice guide
Kyl barnet, närmsta klinik ligger...
26
Säteskylning
27
Avstående lager/färg = blir ej varm/ kall
28
Om inte föräldrar/ hundägare kan nås vid fara
SOS
larmar bilen andra bilar i närheten via wi-fi
29
Robot som tvångs-hämtar förälder/ ägare


30
Larmar smartphones m. sms inom visst avstånd
SOS
SOS
31
Rutor tonas vid solljus
32
Fläs - mätare (ljud inspelning)
33
Skuggtält
34
"Double-door "myggnät"
35
"Bältessensorer" (vikt) larma, inte glömmer
36
Fönster-gardin
37
Alco-sprinkler
38
Intrusensor = ser kroppstemp
39
Sensor in car + device (alarms)
+
40
Open doors automatically
41
Hissa ner helt mtor automatiskt
42
Sätte ut i frisk luft
43
Öppna baggage - lucka
44
AC, sensor inne o ute mäter temp, går igång automatiskt
45
Mäta luft


46
Skylt som påminner.
child in cars
47
FRIE-Igloo
48
Bil som gräver ner sig i sand
49
Väderprognos i bilen → vet om när olc.
50
Bilen skickar
=> Auto-böter hem
Polisen
51
Utbränd på nätet
Bränt = dåtig
52
Bilen lamar tjin butik om överhettad individ =>
butikens högtalare låter meddelande
53
Kameroma märker om skugga flyttar på sig = lamar
54
VARNING
Varning på P-plats
55
Armband, du känner barn/ hunds puls
56
Gör om solenergi/värme till kyla
solcell
57
Mäta puls
= ser stress o hjärt besvär


58
Barn/hund
P
59
"Iron man"
inbyggd temperatur reglerare i kroppen
60
Håller jämn temperatur - även låst
61
Luftavfuktare = svalare
62
Molekyl - energi-kontroll
=> sakta ned molekylerna
63
kylskåps"ägare"
64
Låst tills du även tar barn/hund
65
"Locke in child/dog" tills den är kyld av bilen.
Kylskåp
66
Solskärm = blir natt.
67
Bil-paviljong
68
Kyl-hjälm


69
Blad-fläkt manuell
70
Blöta kläder
71
Fyll m. vatten
72
Inbyggd luftrening
73
Om barn/hund kvar → framkalla stresshormon =slappnar sig tillbaka
79
GPS i bilt-telefon mäter hur långt du går ttid
(larmar om för långt bort/ för länge)
75
Tvinga folk att sitta kvar o ställa larm om hur länge de är borta. Om tiden går ut larmar telefon/armband
76
Armband som blir lika varmt som i bilen + vibrationslarm
77
Skramma folk med högtalare i app om man lämnat.
Child left


78
Hissa ner tak
⇒ cab
79
Blinkar om hund
luar = tar slut på
batteriet.
80
varning på dashboard
81
Bungy-lina =
barnet
följer
med
82
Mäter solstrålar
⇒ gör prognos
på hur länge
man kan vara
borta.
83
Termometer

K Scatter plots with number references

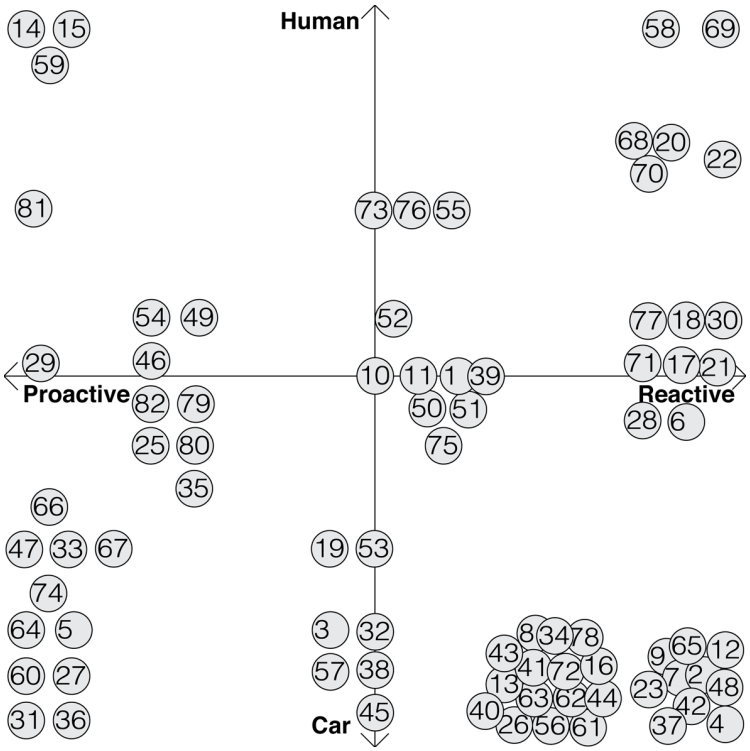


Figure A.12: Scatterplot of concepts including number references

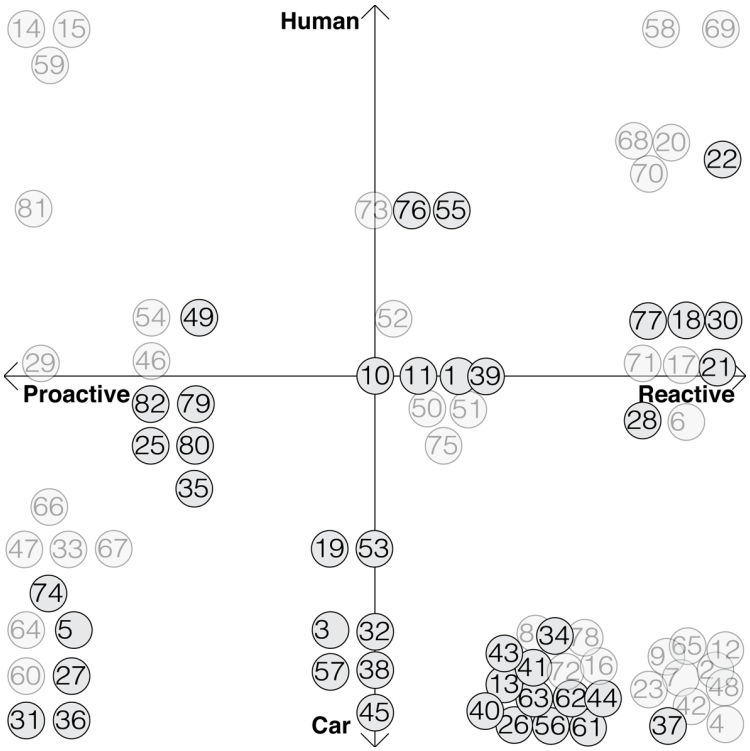


Figure A.13: Scatterplot of concepts after screening including number references

L Adapted Morphological Matrix template

Not possible to leave	**Sensor**	**Maintain cool temperature**
5 Car not possible to lock if somebody is left inside	**3** Camera in car	**13** Open sun roof
	19 Scream monitor	**26** Car seat cooler
	32 Panting monitor	**27** Rejecting paint
	35 Pressure sensor	**31** Darkening windows
	38 Infrared camera	**34** Door with net protection
	45 Measure air	**36** Window curtain
	53 Shadow camera	**40** Automatic door opening
	57 Measure pulse	**41** Lower the windows
	83 Thermometer	**43** Open the trunk lid
		44 AC cooling
		56 Sun energy to cooling
		61 Dehumidifiers
		62 Molecule energy
		63 Refridgerator

Status report	**Call for help**	**Emergency cooling**
49 Weather prognosis in car	**1** Alert owner/parent	**21** Cold water storage
55 Pulse bracelet	**10** Blink at heat	**22** Rescue kit
76 Heat bracelet	**11** Alarm at heat	**25** Voice guide
80 Warning dashboard	**18** Volvo app access to car	
82 Measure sun rays, prognosis	**28** Alert other cars	
	30 Alert smartphones close	
	74 GPS measure time and distance alert owner/parent	
	77 Alarm in app	
	79 Blink if anyone left in car	

M Pugh Matrix

	A	B	C	D	E	F	G	H	I
Selection criteria	**Reference - AC Cooling**	**Car seat concept**	**Pulse-o-meter**	**Hot bracelet**	**Human rescue**	**Solcar cell prognosis**	**Shadow monitor**	**Audio opener**	**Don't leave me**
Prevent heatstroke	S	S	-	+	-	+	-	-	-
Usable in all weather conditions	S	S	S	S	S	S	-	-	S
Usable all around the year	S	S	S	S	S	S	-	-	S
Considers children and dogs left on purpose	S	-	S	S	S	S	S	S	-
Considers children and dogs forgotten	S	S	S	S	S	S	S	S	S
Functions automatically	S	S	-	S	-	S	S	S	-
Functions with car ignition turned off	S	S	+	S	+	+	S	S	+
Do not rely on operator memory	S	S	-	S	S	S	-	S	S
Is trustable	S	-	+	+	S	S	-	-	-
No false feeling of security	S	S	+	S	S	S	S	S	S
Do not encourage leaving	S	+	S	-	+	-	+	+	+
Consider dogs of all types	S	-	-	S	S	S	-	S	-
Consider children of ages 0-6 years	S	S	-	S	S	S	S	S	S
Usable for dogs placed in different ways	S	-	-	S	S	S	-	S	-
Usable for children placed in different ways	S	S	-	S	S	S	S	S	S
General safety of dog or child left	S	-	S	S	-	S	-	-	-
Sum of S	16	10	6	13	11	13	7	10	7
Sum of +	0	0	3	2	2	2	1	1	2
Sum of -	0	5	7	1	2	1	8	5	7
Score	0	-5	-4	1	0	1	-7	-4	-5
Rank	2	4	3	1	2	1	5	3	4

N Needs questionnarie

Default Question Block

Hej!

Vi är två studenter vid Chalmers Tekniska Högskola i Göteborg som skriver vårt examensarbete som handlar om hundar och barn som drabbas av värmeslag för att de har lämnats kvar i bilar som blir varma.

Systemet vi utvecklar ska dels se till att bilen inte blir farligt varm när ett barn/en hund är lämnad däri och dels informera hundägare/förälder eller ansvarig om det mot förmodan blir för varmt. Det är tänkt att fungera för barn mellan åldrarna 0-6 år samt hundar.

Nu behöver vi hjälp att värdesätta olika egenskaper hos systemet. Tack för att ni tar er tid och svarar på enkäten!

Jag har (flervalsfråga):

Hund
Barn

Hur gammal är du (år)?

18-24
25-29
30-39
40-49
50-59
60-69
70-79
80+

Kön?

Man

Kvinna

Varken man eller kvinna

Vilken/Vilka typer av bilar kör du? (flervalsfråga)

Kombi

Sedan

Coupé

Cabriolet

Stadsjeep/SUV

Minibuss

Skåpbil

Kör inte bil

Hur viktigt tycker du följande systemegenskaper är:

	0 Oviktigt	1	2	3	4	5 Mycket viktigt
Inte tillåter permanenta skador på hund/barn	○	○	○	○	○	○
Inte tillåter obehag hos hund/barn	○	○	○	○	○	○
Fungerar om jag har glömt hund/barn	○	○	○	○	○	○
Fungerar om jag har lämnat hund/barn med flit	○	○	○	○	○	○
Finns i bilen när jag köper den	○	○	○	○	○	○
Fungerar i olika väderleksförhållanden	○	○	○	○	○	○
Fungerar under hela året	○	○	○	○	○	○
Tillåter mig att se hur läget är i bilen om en hund/barn sitter där ensam (exempel via telefonen)	○	○	○	○	○	○
Går att lita på	○	○	○	○	○	○

Inte ger falska uppfattningar om säkerheten	○	○	○	○	○	○
Inte uppmuntrar mig att lämna hund/barn i bil	○	○	○	○	○	○
Fungerar utan att jag behöver göra någonting	○	○	○	○	○	○
Fungerar utan att jag behöver komma ihåg någonting	○	○	○	○	○	○
Fungerar utan att bilens motor är igång	○	○	○	○	○	○
Inte innebär att andra kan komma in i bilen	○	○	○	○	○	○
Fungerar för hundar i olika storlekar	○	○	○	○	○	○
Fungerar för barn i olika åldrar, mellan 0-6 år	○	○	○	○	○	○
Fungerar för hundar som är placerade på olika ställen och på olika sätt i bilen	○	○	○	○	○	○
Fungerar för barn som är placerade på olika ställen och på olika sätt i bilen	○	○	○	○	○	○

Andra produktegenskaper jag tycker är viktiga:

O Questionnaire needs rating

Fråga	0 Oviktigt	1	2	3	4	5 Mycket viktigt	Antal svar	Medelvärde
Inte tillåter permanenta skador på hund/barn	1	0	0	0	0	23	24	4,79
Inte tillåter obehag hos hund/barn	1	0	0	0	5	18	24	4,58
Fungerar om jag har glömt hund/barn	1	2	0	1	2	18	24	4,29
Fungerar om jag har lämnat hund/barn med flit	1	0	0	2	2	19	24	4,54
Finns i bilen när jag köper den	3	4	6	4	2	5	24	2,54
Fungerar i olika väderleksförhållanden	1	0	0	4	7	12	24	4,17
Fungerar under hela året	1	0	0	4	5	14	24	4,25
Tillåter mig att se hur läget är i bilen om en hund/barn sitter där ensam (exempel via telefonen)	3	1	1	4	6	9	24	3,5
Går att lita på	1	0	0	0	1	22	24	4,75
Inte ger falska uppfattningar om säkerheten	0	0	0	0	0	24	24	5
Inte uppmuntrar mig att lämna hund/barn i bil	1	0	3	2	3	15	24	4,13
Fungerar utan att jag behöver göra någonting	0	1	5	8	2	8	24	3,46
Fungerar utan att jag behöver komma ihåg någonting	2	0	4	7	3	8	24	3,38
Fungerar utan att bilens motor är igång	1	0	1	0	4	18	24	4,5
Inte innebär att andra kan komma in i bilen	1	2	1	3	2	15	24	4
Fungerar för hundar i olika storlekar	0	0	1	0	4	14	19	4,63
Fungerar för barn i olika åldrar, mellan 0-6 år	1	0	1	0	3	7	12	4,08
Fungerar för hundar som är placerade på olika ställen och på olika sätt i bilen	1	0	4	2	3	9	19	3,74
Fungerar för barn som är placerade på olika ställen och på olika sätt i bilen	1	0	0	0	3	8	12	4,33

P Interview guide fullsystem

Intervjuguide produktintervju

Informera om vårt projekt
Kort om problemet

Vi kommer visa koncept och sen får du fylla i ett frågeformulär som vi diskuterar. Tänk i egenskap av förälder/hundägare som privatperson.

Resultaten presenteras anonymt
Fråga om inspelning

Hur gammal är du?
Hund/barn?
Typ av bil?

Visa och beskriv ett koncept i taget (AC cooling, human rescue, hot bracelet, solcar)
För varje koncept:

1. Beskrivning av konceptet.
2. Semantic differential (ranka), be dem tänka högt när de kryssar i.
3. Diskutera svaren enligt skalan, kommentarer mm.
    a. Varför kryssade du så?
4. Någon funktion som saknas?

(Eventuellt om de är snabba så kan man fråga om deras beteenden när de har hund/barn i bil, vilken information de vill ha från ett system, vilka funktioner mm.)

Q Semantic differential

Safe						Dangerous
Reliable						Unreliable
Integrated						Separate
Automatic						Manual
Useful						Useless
Versatile						Limited
Expensive						Cheap
Luxurious						Plain
Comfortable						Uncomfortable
Discreet						Indiscreet
Secure						Unsecure
Easy to use						Hard to use
Simple						Complicated
Encouraging						Limiting

R Volvo On Call interface interview guide

Intro

- Informera om exjobbet
- Informera om testet, Du äger en Volvo XC90 och du ska testa en app som är kopplad till din Volvo.
- Fråga om spela in
- Nu ska du få fylla i en enkät, på andra delen får du gärna berätta hur du tänker

Scenario 1 - Parkeringsvärmare

- Ge mobilen med startskärmen "inloggad"
- Du ska precis gå hemifrån och vill kolla hur varmt det är vid bilen och värma upp den på distans på direkten. Tänk gärna högt när du använder appen. Säg till när du känner dig klar. *(Parkeringsklimat)*
    - Notera hur de går tillväga i sheet
    - Notera om de klarar det utan hjälp/med hint/med hjälp

Anteckna till följande frågor:

- Hur tyckte du att det gick?
- Fick du feedback på det du gjort? Hur?
- Uppfattade du om det fanns det andra sätt att lösa uppgiften på än ditt sätt?

Scenario 2 - Destination IKEA

- Du ska åka iväg till IKEA Bäckebol och ska använda appen för att lägga in destinationen i bilen, eftersom du inte hittar. Tänk gärna högt när du använder appen. Säg till när du känner dig klar. *(Karta/skicka resmål)*
    - Notera hur de går tillväga i sheet
    - Notera om de klarar det utan hjälp/med hint/med hjälp

Anteckna till följande frågor:

- Hur tyckte du att det gick?
- Fick du feedback på det du gjort? Hur?
- Uppfattade du om det fanns det andra sätt att lösa uppgiften på än ditt sätt?

Scenario 3 - Stressa låsa bilen

- Du är påväg och redan sen till ett möte och kommer på att du glömde låsa bilen och inte hinner gå tillbaka. Utför detta fortast möjligt. *(Dörrar och lås, swipe:a)*
    - Notera hur de går tillväga i sheet
    - Om de inte hittar swipen, fråga vad de tror strecken är till för
    - Notera om de klarar det utan hjälp/med hint/med hjälp

Anteckna till följande frågor:

- Hur tyckte du att det gick?
- Fick du feedback på det du gjort? Hur?
- Uppfattade du om det fanns det andra sätt att lösa uppgiften på än ditt sätt?

Scenario 4 - Köpa spolarvätska

- Du är på ICA Maxi och kommer på att du vill kolla om du har tillräckligt med spolarvätska i bilen så att du vet om du ska köpa ny. Tänk gärna högt när du använder appen. Säg till när du känner dig klar. *(Varningar)*
    - Notera hur de går tillväga i sheet
    - Notera om de klarar det utan hjälp/med hint/med hjälp

Anteckna till följande frågor:

- Hur tyckte du att det gick?
- Fick du feedback på det du gjort? Hur?
- Uppfattade du om det fanns det andra sätt att lösa uppgiften på än ditt sätt?

Slutfrågor

- Hur upplevde du:
    - Appen överlag?
    - Symbolerna?
    - Responsen från ditt agerande (förstod du att den fungerade?)
    - Att det gick att utföra scenariona efter scenario ett, blev det någon skillnad?
- Vad var enklast med användningen?
- Vad var svårast med användningen?

S Volvo On Call interface survey

Om dig:

Namn: _____

Smartphonevana

Ingen	Liten	Genomsnittlig	Stor	Mycket stor

Vana av nya bilar (koll på moderna funktioner)

Ingen	Liten	Genomsnittlig	Stor	Mycket stor

Teknisk kunskap om bilar generellt

Ingen	Liten	Genomsnittlig	Stor	Mycket stor

Synfel: _____

Enkät om symboler

Vad tror du att följande symboler betyder?

T FMEA

FAILURE MODE AND EFFECTS ANALYSIS										
Item:	HeatSafe system			Responsibility:		MT & JE			FMEA number:	1
Model:	1			Prepared by:		MT & JE			Page :	1 of 1
Core Team:	Meltem Temur and Josephine Eriksson								FMEA Date :	2016-04-26
Process Function	**Potential Failure Mode**	**Potential Effect(s) of Failure**	**Potential Cause(s)/ Mechanism(s) of Failure**	**Current Process Controls**	**Severity**	**Occurence**	**Detectability**	**RPN**	**Recommended Action(s)**	**Responsibility**
Thermometer	Error in temperature reading.	Unable to start camera and AC in time, unable to send heat warning in time.	Production error, installation error.	Unknown	9	2	2	36	Factory control of thermometer before and after installation.	Volvo Cars AB, thermometer manufacturer.
Thermometer	Lack of power input.	Unable to start system.	Production error, installation error, wear, bad contact, power supply shortage.	Unknown	10	2	2	40	Factory control of thermometer after installation, power supply buffert.	Volvo Cars AB
Thermometer	Error in transferring data to software.	Unable to start system.	Production error, installation error, wear, bad contact.	Unknown	10	2	2	40	Factory control of thermometer after installation.	Volvo Cars AB
Software	Lack of power input.	Unable to transfer information between components, system unable to function.	Production error, installation error, power supply shortage.	Unknown	10	3	2	60	Factory control of software after installation, power supply buffert.	Volvo Cars AB
Software	Software error	Unable to transfer information between components, system unable to function.	Component performance, non-optimal programming, over-heating.	Unknown	10	3	7	210	Select components with lasting performance. Service of software related hardware regularly.	Volvo Cars AB
Software	Error in thermometer temperature comparison.	Starting AC or camera too early or too late. Wrong timing with warning notifications.	Incorrect programming.	Unknown	8	2	4	64	Proper testing.	Volvo Cars AB
Software	Loop error.	Starting AC or camera at wrong temperature, sending warning notifications at wrong temperature.	Incorrect programming, software error.	Unknown	9	3	5	135	Proper testing. Select components with lasting performance. Service of software related hardware.	Volvo Cars AB

FAILURE MODE AND EFFECTS ANALYSIS

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Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Potential Cause(s)/ Mechanism(s) of Failure	Current Process Controls	Severity	Occurence	Detectability	RPN	Recommended Action(s)	Responsibility
Software	Motion computation error.	Unable to detect living being.	Incorrect programming, software error.	Air motion detection system.	6	2	5	60	Proper testing. Select components with lasting performance, proper programming. Use existing back-up systems (air motion and camera heat detection) to detect living being.	Software engineer, Volvo Cars AB
Software	Reference image not usable.	Unable to detect living being.	Incorrect reference image, too few reference images.	Unknown	4	1	5	20	Perform studies to select proper reference images.	Software engineer
Software	Unable to distinguish living being from background.	Unable to detect living being.	Non-sufficient camera accuracy, non-sufficient image accuracy, skin/fur reaches same temperature as interior, programming error.	Unknown	10	3	7	210	Select camera with sufficient accuracy, proper programming. Use additional system (motion detection) to detect living being.	Software engineer, project group.
Software	Object temperature reading not correct.	Unable to detect living being, starting AC at wrong temperature, sending warning notifications at wrong timing.	Non-sufficient camera and image accuracy. Programming error.	Thermometer comparison.	10	2	3	60	Proper testing, proper programming, select camera with sufficient accuracy.	Volvo Cars AB, software engineer, project group.
Software	Lack of phone connection.	Unable to inform user about situations inside of car. Unable to get user permission to start AC.	Car wi-fi trouble, software error.	Unknown	7	4	7	196	Select components with lasting performance. Service of software related hardware regularly. Ensure connection to phone.	Volvo Cars AB

FAILURE MODE AND EFFECTS ANALYSIS

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Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Potential Cause(s)/ Mechanism(s) of Failure	Current Process Controls	Severity	Occurence	Detectability	RPN	Recommended Action(s)	Responsibility
Software	Sends wrong information to phone.	User does not interpret situation correctly, might choose not to return to car in time or return too early.	Incorrect programming, software error, loop error.	Unknown	7	2	5	70	Select components with lasting performance. Service of software related hardware regularly. Correct programming.	Software engineer, Volvo Cars AB
Software	Sends information with wrong timing.	User returns too late or too early to car.	GPS error, incorrect programming, software error.	Unknown	7	3	8	168	Select components with lasting performance. Service of software related hardware regularly. Correct programming.	Software engineer, Volvo Cars AB
Software	Unable to detect position of user.	System unable to notify user in time.	Lack of connection, GPS error, software error, incorrect programming.	Unknown	8	8	8	512	Send notifications with default timing. Select components with lasting performance. Service of software related hardware regularly. Correct programming.	Software engineer, Volvo Cars AB, project group.
Software	Unable to send information to phone.	User not informed about situation, unable to return.	Software error, wear, lack of connection, incorrect programming.	Unknown	9	3	5	135	Select components with lasting performance. Service of software related hardware regularly. Correct programming.	Software engineer, Volvo Cars AB
Software	Sends wrong information about desired temperature to AC.	AC provides too hot air, does not cool living being left in car.	Incorrect programming, software error.	Thermometer detects unexpected rise in temperature.	8	2	3	48	Shut down AC. Proper testing, correct programming.	Software engineer, Volvo Cars AB
Software	Not able to detect malfunctioning AC.	Unable to notify user on AC malfunction.	Incorrect programming, software error.	Unknown	8	3	5	120	Proper testing, correct programming.	Software engineer, Volvo Cars AB

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Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Potential Cause(s)/ Mechanism(s) of Failure	Current Process Controls	Severity	Occurence	Detectability	RPN	Recommended Action(s)	Responsibility
Camera	Lack of power input.	Unable to detect living being.	Production error, installation error, wear, bad contact, power supply shortage.	Unknown	10	2	2	40	Factory control of camera after installation, power supply buffert.	Volvo Cars AB
Camera	Camera heat damaged	Unable to detect living being.	Camera model not suitable for purpose, extreme conditions.	Unknown	10	2	2	40	Select proper camera model, test camera if car has been in extreme conditions.	Volvo Cars AB, project group.
Camera	Camera humidity damaged.	Unable to detect living being.	Camera model not suitable for purpose, extreme conditions.	Unknown	10	2	2	40	Select proper camera model, test camera if car has been in extreme conditions.	Volvo Cars AB, project group.
Camera	Impact damaged camera.	Unable to detect living being.	Camera model not suitable for purpose, extreme conditions.	Unknown	10	4	2	80	Select proper camera model, test camera if car has been in extreme conditions.	Volvo Cars AB, project group.
Camera	Camera not started by software.	Unable to detect living being.	Incorrect programming, software error.	Unknown	10	3	2	60	Select components with lasting performance. Service of software related hardware regularly. Correct programming.	Software engineer, Volvo Cars AB
Camera	Camera vision impairment.	Unable to detect living being.	Dirt on lens, obstacle in line of sight.	Unknown	10	3	8	240	Service of cameras, provide warning to user if a camera has vision impairment.	Project group, Volvo Cars AB
Camera	Vision field limited.	Unable to detect living being.	Too small field of view, wrong placement of camera.	Unknown	10	2	3	60	Select proper camera, test camera after installation.	Project group, Volvo Cars AB.
Camera	Not enough temperature accuracy.	Unable to detect living being.	Camera not suitable for purpose.	Unknown	10	2	2	40	Select proper camera.	Project group.
Camera	Error in transferring data to software.	Unable to detect living being.	Hardware connection error, wear, installation error, hardware damage.	Unknown	10	3	4	120	Proper testing and installation procedure, regular service.	Volvo Cars AB.

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Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Potential Cause(s)/ Mechanism(s) of Failure	Current Process Controls	Severity	Occurence	Detectability	RPN	Recommended Action(s)	Responsibility
AC	No battery power or petrol/diesel.	Unable to cool living being.	User has not refilled battery/petrol/ diesel, battery discharged, software misinterpretation of battery/petrol/ diesel buffert.	Unknown	7	6	8	336	Provide warnings to user that AC is unable to start, provide warning that battery/petrol/ diesel needs refilling.	Project group, Volvo Cars AB.
AC	AC hardware error	Unable to cool living being.	Production error, installation error, wear, bad contact.	Unknown	7	3	5	105	Regular service, testing, provide warning to user.	Project group, Volvo Cars AB.
AC	Unable to receive start command.	Unable to cool living being.	Hardware connection error, wear, installation error, hardware damage, programming error, software error.	Unknown	7	2	2	28	Proper testing and installation procedure, regular service, correct programming, select proper components.	Volvo Cars AB.
Application	Phone unable to show push-notifications (while turned on).	Unable to get information in time.	Phone settings, software error, programming error.	Unknown	7	5	5	175	Proper programming.	Software engineer.
Application	Phone turned off.	User unable to return to car in time. User unable to get information about situation.	Lack of battery power, user has turned off phone, hardware error.	Unknown	9	7	10	630	Ensure AC starts anyway.	Project group, software engineer.
Application	Phone not connected to car (while turned on).	User unable to return to car in time. User unable to get information about situation.	Lack of internet connection, software error, phone not compatible with system.	Unknown	9	6	10	540	Ensure AC starts anyway.	Project group, software engineer.
Application	Application not installed in phone.	User unable to return to car in time. User unable to get information about situation.	Phone not compatible with application, user has not installed application.	Unknown	9	2	10	180	Car display can remind user to install application. Include optional compatible phone when buying car.	Project group, Volvo Cars AB.

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Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Potential Cause(s)/ Mechanism(s) of Failure	Current Process Controls	Severity	Occurence	Detectability	RPN	Recommended Action(s)	Responsibility
Application	Phone software error.	Application unable to start.	Component performance, non-optimal programming, over-heating.	Unknown	9	7	10	630	Include phone service at car service. Include optional compatible phone when buying car.	Volvo Cars AB.
Application	Wrong language settings in application.	User unable to understand information.	Use error, telephone language settings wrong, software error.	Unknown	7	2	10	140	Separate setting in application for language.	Project group, Volvo Cars AB.
Application	User unable to interpret information.	User does not return to car in time. User does not start AC.	Information unclear, user has vision impairment, user has dyslexia.	Unknown	9	2	10	180	Start AC automatically. Ensure that information provided is comprehensive.	Project group, Volvo Cars AB.
Application	User ignores notification.	AC is not started, user does not return to car.	User does not realise importance of message, user does not distinguish notification from other application notifications.	Unknown	9	4	10	360	Start AC automatically, make information comprehensible and distinguishable in notification.	Project group, Volvo Cars AB.
Application	Vibration and sound not working.	User unable to detect notifications.	Phone hardware error, phone settings, wear.	Unknown	8	7	10	560	Start AC anyway.	Project group, software engineer.
General	Dog or child covered by object.	Camera unable to detect.	User has placed object, dog or child has moved.	Unknown	10	3	10	300	Start camera often, provide information on non-detected living being in application.	Project group, software engineer.
General	False alarm on motion.	Unnecessary alarm and AC start.	Windows open (wind blowing and moving object).	Unknown	3	4	10	120	Automatically close windows if open and suspecting living being inside of car to determine if wind or not.	Software engineer, project group.
General	False alarm from non-living object.	Unnecessary alarm and AC start.	Camera not suitable for purpose, non-living object having body temperature.	Unknown	3	4	10	120	Check for motion.	Software engineer, project group.

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Core Team:	Meltem Temur and Josephine Eriksson			FMEA Date :	2016-04-26

Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Potential Cause(s)/ Mechanism(s) of Failure	Current Process Controls	Severity	Occurence	Detectability	RPN	Recommended Action(s)	Responsibility
General	User decides not to return to car.	Hyperthermia among living being left in car.	User has not interprated the severty of situation, user does not care, user not in regular condition.	Unknown	10	2	10	200	Provide information that clearly expresses severity, provide number to call for help in application.	Software engineer, project group.
General	User not carrying phone.	User unable to return to car in time. User unable to get information about situation.	User has forgotten phone, user has left phone on purpose, user has lost phone.	Unknown	9	6	10	540	Car reminds user to bring phone when leaving car.	Volvo Cars AB.