Persuasive Technology

To Mitigate Aggressive Driving

A Human-centered Design Approach

Inaugural-Dissertation

zur Erlangung der Doktorwürde der Fakultät für Humanwissenschaften der Julius-Maximilians-Universität Würzburg vorgelegt von Monique Dittrich aus Stuttgart

Würzburg

2020

Persuasive Technology To Mitigate Aggressive Driving

A Human-centered Design Approach

Inaugural-Dissertation zur Erlangung der Doktorwürde der Fakultät für Humanwissenschaften der Julius-Maximilians-Universität Würzburg vorgelegt von Monique Dittrich aus Stuttgart

Würzburg
2020

Erstgutachter:	Professor Dr. Jörn Hurtienne
Zweitgutachter:	Professor Dr. Sarah Diefenbach

Tag des Kolloquiums:	10. Dezember 2020

Für *unser* Klingelschild.

NOTE

Collaboration Partner

This thesis is an industry-sponsored doctoral dissertation that was conducted at the Chair for Psychological Ergonomics at the University of Würzburg in cooperation with the Innovation Studio of the Mercedes-Benz AG. Mercedes-Benz is a subsidiary of the Daimler Group that is one of the world's biggest manufacturer of commercial vehicles and premium automobiles. Within the corporation, Mercedes-Benz controls the global business of Mercedes-Benz Cars and Mercedes-Benz Vans with approximately 175,000 employees worldwide. The focus is on the development, production, and sale of cars and vans as well as on the provision of related products and services. In addition to the Mercedes-Benz brand, the product portfolio comprises the sub-brands Mercedes-AMG, Mercedes-Maybach, Mercedes me, smart, and EQ (for electric mobility products and technology). The Innovation Studio is a research and development department that is aimed at supporting product innovation processes within the corporation. For this, the Innovation Studio team provides methodological know-how, suitable premises, and material equipment for prototyping sessions, ideation workshops, or agile projects. For more information, see

https://www.daimler.com/innovation/pioneering/ideation.html.

Gender Disclaimer

For the sake of readability, the male form of words is generally used in this thesis. However, any personal terms put down in their male form may refer to both female and male persons.

ABSTRACT

Manifestations of aggressive driving, such as tailgating, speeding, or swearing, are not trivial offenses but are serious problems with hazardous consequences—for the offender as well as the target of aggression. Aggression on the road erases the joy of driving, affects heart health, causes traffic jams, and increases the risk of traffic accidents. This work is aimed at developing a technology-driven solution to mitigate aggressive driving according to the principles of *Persuasive Technology*. Persuasive Technology is a scientific field dealing with computerized software or information systems that are designed to reinforce, change, or shape attitudes, behaviors, or both without using coercion or deception.

Against this background, the *Driving Feedback Avatar* (DFA) was developed through this work. The system is a visual in-car interface that provides the driver with feedback on aggressive driving. The main element is an abstract avatar displayed in the vehicle. The feedback is transmitted through the emotional state of this avatar, i.e., if the driver behaves aggressively, the avatar becomes increasingly angry (negative feedback). If no aggressive action occurs, the avatar is more relaxed (positive feedback). In addition, directly after an aggressive action is recognized by the system, the display is flashing briefly to give the driver an instant feedback on his action.

Five empirical studies were carried out as part of the human-centered design process of the DFA. They were aimed at understanding the user and the use context of the future system, ideating system ideas, and evaluating a system prototype. The initial research question was about the triggers of aggressive driving. In a driver study on a public road, 34 participants reported their emotions and their triggers while they were driving (study 1). The second research question asked for interventions to cope with aggression in everyday life. For this purpose, 15 experts dealing with the treatment of aggressive individuals were interviewed (study 2). In total, 75 triggers of aggressive driving and 34 anti-aggression interventions were identified. Inspired by these findings, 108 participants generated more than 100 ideas of how to mitigate aggressive driving using technology in a series of ideation workshops (study 3). Based on these ideas, the concept of the DFA was elaborated on. In an online survey, the concept was evaluated by 1,047 German

respondents to get a first assessment of its perception (study 4). Later on, the DFA was implemented into a prototype and evaluated in an experimental driving study with 32 participants, focusing on the system's effectiveness (study 5). The DFA had only weak and, in part, unexpected effects on aggressive driving that require a deeper discussion.

With the DFA, this work has shown that there is room to change aggressive driving through Persuasive Technology. However, this is a very sensitive issue with special requirements regarding the design of avatar-based feedback systems in the context of aggressive driving. Moreover, this work makes a significant contribution through the number of empirical insights gained on the problem of aggressive driving and wants to encourage future research and design activities in this regard.

ZUSAMMENFASSUNG

Aggressives Fahren, egal ob Drängeln, Rasen oder Fluchen, ist kein Kavaliersdelikt, sondern ein ernstzunehmendes Problem mit schwerwiegenden Folgen—sowohl für den Täter als auch für das Opfer. Es nimmt die Freude am Fahren, beeinträchtigt die Herzgesundheit, verursacht Stau und erhöht das Unfallrisiko. Ziel dieser Arbeit war es daher nach den Prinzipien persuasiver Technologie (engl. Persuasive Technology) eine technische Lösung zu entwickeln, die aggressives Fahren verringert. Als persuasiv werden Systeme bezeichnet, die ein bestimmtes Verhalten oder eine bestimmte Einstellung ihres Nutzers verstärken, verändern oder formen, ohne dabei Zwang auf ihn auszuüben oder ihn zu täuschen.

Vor diesem Hintergrund wurde im Rahmen dieser Arbeit der sogenannte *Driving Feedback Avatar* (DFA) entwickelt. Das System ist eine visuelle Benutzerschnittstelle im Fahrzeug, die dem Fahrer Rückmeldung zu bestimmten aggressiven Verhaltensweisen gibt. Hauptelement ist ein abstrakter Avatar, der in einem Display angezeigt wird. Das Feedback selbst wird durch den emotionalen Zustand dieses Avatars vermittelt. Verhält sich der Fahrer aggressiv, wird er zunehmend wütender (negatives Feedback). Legt der Fahrer hingegen keine aggressiven Verhaltensweisen an den Tag, zeigt sich der Avatar nach und nach entspannter (positives Feedback). Darüber hinaus erhält der Fahrer ein sofortiges Feedback, indem das Display kurz aufblinkt, direkt nachdem eine aggressive Handlung vom System erkannt wurde.

Zur Entwicklung des Systems wurden, unter Einsatz menschenzentrierter Forschungsmethoden, insgesamt fünf empirische Studien durchgeführt. Diese dienten dazu, den Nutzer und den Nutzungskontext des zukünftigen Systems zu verstehen, Ideen für mögliche Systeme zu entwickeln und die finale Lösung anhand eines Prototypens zu evaluieren. Zunächst stand dabei die Forschungsfrage im Raum, welche Auslöser für aggressives Fahren es heute gibt. In einer Fahrerstudie auf öffentlicher Straße berichteten dazu 34 Teilnehmer während der Fahrt von ihren Emotionen und deren Auslösern (Studie 1). Die zweite Forschungsfrage ergründete Maßnahmen zur Bewältigung von Aggression im Alltag. Hierzu wurden 15 Experten, die sich beruflich mit der Behandlung von aggressiven Personen befassen, interviewt (Studie 2). Insgesamt konnten so 75 Auslöser aggressiven

Fahrens und 34 Maßnahmen zur Regulierung von Aggression im Allgemeinen abgeleitet werden. Inspiriert von diesen Erkenntnissen, entwickelten 108 Teilnehmer in einer Reihe von Workshops mehr als 100 Ideen, wie Aggression beim Fahren, unter Einsatz von Technologie, verringert werden könnte (Studie 3). Basierend auf diesen Ideen, entstand das Konzept des DFA. In einer Onlineumfrage mit 1.047 deutschen Teilnehmern wurde das Konzept evaluiert, um eine erste Bewertung der Wahrnehmung des Systems zu erhalten (Studie 4). Später wurde der DFA prototypisch umgesetzt und dessen Effektivität in einer Fahrerstudie unter experimentellen Bedingungen untersucht (Studie 5). Es zeigte sich, dass das System nur schwache und in Teilen auch unerwartete Effekte hat, die eine eingehende Diskussion verlangen.

Diese Arbeit hat gezeigt, dass es möglich ist, aggressives Fahren mit Hilfe persuasiver Technologie zu beeinflussen. Jedoch ist dies ein sehr sensibles Vorhaben, das besondere Anforderungen an das Design Avatar-basierter Feedbacksysteme im Kontext aggressiven Fahrens stellt. Darüber hinaus leistet diese Arbeit vor allem aufgrund der gewonnenen empirischen Erkenntnisse rund um das Problem aggressiven Fahrens einen wichtigen Beitrag für Wissenschaft und Praxis und will zu weiteren Forschungs- und Designaktivitäten anregen.

DANKSAGUNG

Zu allererst möchte ich drei ganz besondere Menschen erwähnen. *Dr. Stefan Mattes*, mein Betreuer „beim Daimler“, ich danke dir für die Zeit und die Gedanken, die auch du in diese Arbeit investiert hast. Ohne deinen Rat—egal ob wissenschaftlich oder privat—wäre diese Arbeit nicht das, was sie heute ist. *Marco Anselmann*, die Person, die nicht nur in Bezug auf diese Arbeit, sondern auch darüber hinaus, in den letzten Monaten mein Fels in der Brandung war. Du gibst mir das Gefühl, stolz auf mich sein zu können. An dieser Stelle möchte ich dir sagen: Ich bin unglaublich stolz auf dich. *Martin Nothstein*, mein Mitbewohner, auch du bist seit Tag eins ein fester Bestandteil dieser Arbeit. Dir möchte ich vor allem dafür danken, dass du tagtäglich meine Launen ertragen hast, dich über jeden meiner Fortschritte gefreut hast, und mir immer wieder das Gefühl gegeben hast, dass das, was ich hier tue, wichtig ist.

Daneben danke ich *Rebecca Frenz* (für tagelanges Korrekturlesen und seelischen Support), *Sebastian Zepf* (für unser tolles Teamwork und eine unvergessliche Partynacht in Böblingen), *Peter Gödecke* und *Dr. Holger Enigk* (dafür, dass ihr mir all das hier ermöglicht habt und euch immer für mich eingesetzt habt) und allen Studenten, die mich im Laufe der Zeit unterstützt haben—vor allem aber *Nils Matthew(s)* und *Chunhui Zhu*.

Zu guter Letzt gilt mein Dank Herrn *Prof. Dr. Jörn Hurtienne*, meinem Doktorvater. Insbesondere weil es sich bei meiner Arbeit um eine Industriepromotion handelt, weiß ich die Zeit, die Sie in mich investiert haben, zu schätzen. Darüber hinaus danke ich Ihnen für Ihre Offenheit gegenüber mein Thema und Ihr Wissen, das Sie mit mir geteilt haben. Ich bewundere Sie für Ihre Begeisterung für neue Themen und Ihre Fähigkeit, sich in diese hineindenken zu können.

CONTENT

FIGURES

TABLES

I. CHAPTER

INTRODUCTION

1.1 Motivation

White van driver Lee McClaren repeatedly crossed double white lines on the A361 North Devon link road as he tried to overtake and box in a silver Honda. He lost his temper because he thought he had been carved up by the other driver and tried to force him to stop. The dashcam in his Transit had a voice recorder which captured his foul mouthed rants during the chase. He could be heard shouting “I'm going to f***ing kill' him” repeatedly on the footage, which was shown at Exeter Crown Court. McClaren, who is 6'4'' tall and heavily built, managed to stop Honda driver Luke Fisher twice. On the first occasion Mr Fisher drove away before he reached the car, but the second time he kicked dents in the doors and smashed a side window with his fist [...].

McClaren, aged 35, of Moorfield Close, Exmouth, admitted dangerous driving and criminal damage and was jailed for 18 weeks and banned from driving for two years by Judge David Evans at Exeter Crown Court. The judge told him: “The car driven by Mr Fisher did cut across your path a little abruptly, but what happened thereafter, quite frankly, has to be seen to be believed. There was no justification whatsoever for the astonishingly dangerous way in which you then drove. It is clear that you lost all self control and

> were unable to master your all-consuming anger. The dangerousness with which you drove was breath-taking. You pursued Mr Fisher, who was scared and did not know what to do. You continued to pursue him, putting all sorts of people at risk. It was clearly your intention to get him out of his car to have some form of physical confrontation. What you were really after was a straightforward fist fight. There is no wonder he was scared. This was serious, prolonged, and quite deliberate aggressive driving. It as a true road rage incident." (Cooper, 2020)

This section of a newspaper article is an illustrative example of an extreme manifestation of aggressive driving or, in colloquial speech, road rage. However, aggressive driving is not always shown through physical violence. It also includes forms of aggression without physical contact (e.g., offensive tailgating or risky overtaking) and communicative aggression (e.g., obscene gestures or insulting words). Most of us are affected by aggressive driving, either as the aggressive offender or as a victim (AAA Foundation for Traffic Safety, 2016). Some of us, however, are more likely to behave aggressively behind the wheel than others. "The ones most likely to run a red light, not give way to pedestrians and generally drive recklessly and too fast were often the ones driving fast German cars," says Jan-Erik Lönnqvist, professor of social psychology at the University of Helsinki (Gröning, 2020). In their study "Not Only Assholes Drive Mercedes", Lönnqvist, Ilmarinen, and Leikas (2019) found out that regardless of income, disagreeable men and conscientious people in general were particularly likely to drive high-status cars, such as Audi, BMW, Jaguar, Lexus, or Mercedes-Benz. By implication, drivers of powerful cars were more likely to behave aggressively behind the wheel. Besides, other personality attributes, such as a macho attitude or younger age, also correlate with aggressive driving (Krahé & Fenske, 2002).

Whether you are the aggressor or the target, there are hazardous consequences for both sides on a social and individual level. On the social level, aggressive driving has an impact on the number of traffic accidents and the formation of congestion. Every year, the German Federal Statistical Office publishes the number of driver-related causes of traffic accidents with personal injury, considering drunk driving, improper road use, inappropriate speed, insufficient distance, overtaking mistakes, failure to yield right of way, turning off mistakes or mistakes in starting off or entering the road from premises, and improper behavior toward pedestrians (Statistisches Bundesamt, 2019a). In 2018, 368,559 incidents were registered. In relation to the number of people with a driving license, around one out of 150 drivers is a victim of aggressive driving (Statistisches Bundesamt, 2020a). Moreover, there is a positive relationship between the annual kilometers of congestion and the number of registered speeding violations (Figure 1.1.1), with a radical decrease in the last decade (Statistisches Bundesamt, 2019b, 2020c).

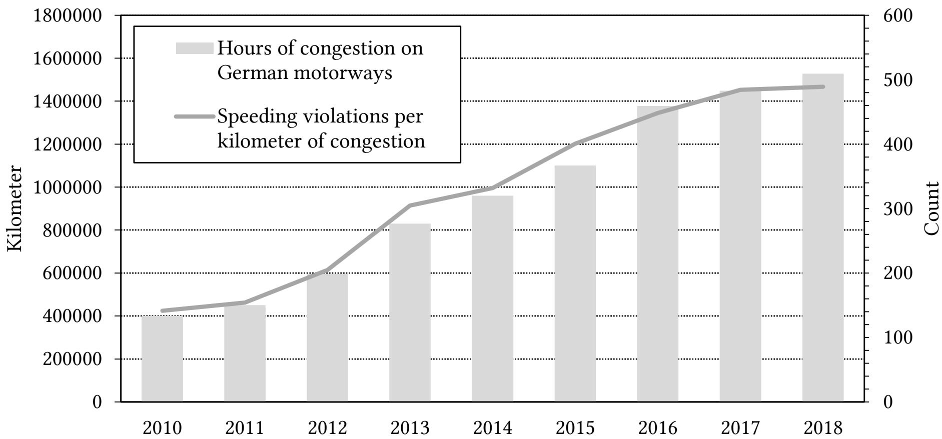


Figure 1.1.1. Development of congestion and speeding violations in Germany (Statistisches Bundesamt, 2019b, 2020c).

On the individual level, aggressive driving has serious health-related consequences that go beyond the injuries of a traffic accident. For example, as the University of the Sunshine Coast revealed, there is a link between aggressive driving and cardiovascular diseases (Yagana, 2016). In a study, participants driving in a driving simulator were exposed to other drivers who were either aggressive or considerate. Considerate drivers had a positive effect on the participants, so that they also drove considerately and had a low level of stress. In contrast, aggressive drivers caused participants to make driving errors and increased their stress level. This kind of stress is associated with higher resting blood pressure, which contributes to cardiovascular diseases and other health problems in the long-term.

Various measures have already been developed to counteract aggressive driving, such as speeding cameras and speed limits (Zeit, 2020), intelligent speedometers that automatically report violations to the police (Lobe, 2020), or insurance programs that track one's driving behavior and offer lower premiums for "good drives" (Kern, 2013). However, these interventions are based on coercion, deception, or material inducement, which contradicts the fundamental human need for freedom (Brehm, 1966). Moreover, they only have short-term effects. For instance, near the speeding camera, people tend to drive even below the posted speed limit. As soon as the surveillance has been passed, drivers start to exceed the speed limit again (Mäkinen et al., 2003). In conclusion, aggressive driving is a serious problem that has to be solved. Existing interventions are ineffective and not human-centered, which calls for an alternative solution.

1.2 Research Objective

Following the previous considerations, there is the need to find a solution that mitigates aggressive driving without using coercion, deception, or material inducement. Thus, this work is situated in the field of *Persuasive Technology* that deals with technology that is designed to cause voluntary changes in one's attitude or behavior (Oinas-Kukkonen & Harjumaa, 2008). Accordingly, the research objective is to *develop a Persuasive Technology solution to effectively mitigate aggressive driving*. Due to the author's scope of research on Human-Computer-Interaction (HCI) in the automotive domain, the car is considered as a platform for this purpose. The use context and the user of the future system are specified as follows:

(i) The context of use is the road with a special focus on the highway. The decision for this type of road was made because it is assumed that accidents caused by aggressive driving are more severe the faster people drive (European Commission, 2018).

(ii) The user refers to "normal" people who behave aggressively from time to time while driving a car and excludes pathologically or criminally aggressive individuals.

After the subjects of research, i.e., the phenomenon of aggressive driving and the idea of Persuasive Technology, have been theoretically discussed, several empirical studies are conducted to address the research objective. By this, this work is aimed at providing a prototype that makes the future system tangible.

1.3 Overview

Following this introduction, *chapter II* provides the theoretical foundations and underlying assumptions of this thesis by reviewing relevant literature on aggressive driving and Persuasive Technology. A model of the formation and change of aggressive driving and central approaches from Persuasive Technology are introduced. The chapter also presents related work focusing on technical and non-technical interventions to change negative driving behavior. In conclusion, the research and design activities conducted within this work and the initial research questions are outlined.

Chapters III to *VII* describe the empirical studies conducted within this thesis. *Chapter III* is aimed at identifying the emotional triggers of aggression in modern driving. For this purpose, a naturalistic driving study in real traffic was conducted, in which participants were asked about negative and positive emotional experiences and their triggers while driving (study 1). As a result, a comprehensive overview of aggressive driving triggers is presented.

Chapter IV asks for strategies people use to regulate aggression in everyday life. In order to identify effective anti-aggression interventions, 15 experts concerned with human aggression professionally (e.g., psychotherapists, probation officers, martial artists) were interviewed (study 2). The outcome of this investigation is a classification scheme of anti-aggression interventions, including illustrative and extraordinary examples.

Chapter V presents the results of six ideation workshops, in which participants generated innovative ideas to mitigate aggressive driving (study 3). The ideas are summarized and assessed by an expert panel in terms of their innovative potential.

The author of this thesis elaborates the ideas gained in the workshops. As a result, the *Driving Feedback Avatar* (DFA) concept is introduced in *chapter VI*. The concept describes an in-vehicle system that provides the driver with feedback on his driving performance with a special focus on aggressive driving. At the end of the chapter, the concept is evaluated in an online survey (study 5).

In *chapter VII*, the DFA is evaluated in more detail. For this, a driving study in real traffic was conducted (study 6). Using a within-subjects design, participant drivers completed a test drive with and without a prototype of the system, while their driving behavior was logged. Based on this data, the perception and effectiveness of the DFA within both conditions was compared.

Finally, *chapter VIII* reviews the empirical part of this thesis and highlights the main contributions to research and practice. The chapter closes by pointing to future directions and providing design implications for future systems.

II. CHAPTER

THEORETICAL BACKGROUND

2.1 Aggressive Driving

> The current hot issue in driver behavior and traffic safety is "Aggressive Driving", also known as "Road Rage." I believe that what we are dealing with is an old issue but on a scale that is new and bigger than ever before. The old issue is that of aggressive drivers, and the new phenomenon is that of ubiquitous aggressive driving that we see all around us. (Shinar, 1998, p. 138)

This statement—which was claimed over 20 years ago—demonstrates that the problem of aggressive driving is not new. A number of definitions have emerged over time, making aggressive driving a loose and inconsistently used construct in the scientific literature and everyday language (Dula & Geller, 2003). The following sections address this definitional ambiguity and explain how overt aggression behind the wheel arises and how it can be mitigated.

2.1.1 Definitional Ambiguity of Aggressive Driving

The understanding of aggressive driving that underlies the present work refers to the definition of Shinar (1998), who describes the phenomenon as

> a syndrome of frustration-driven instrumental behaviors which are manifested in: (a) inconsiderateness toward or annoyance of other drivers (tailgating, flashing lights, and honking at other drivers), and (b) deliberate dangerous driving to save time at the expense of others (running red lights and stop signs, obstructing path of others, weaving). (p. 139)

This definition is founded on the distinction between instrumental and hostile aggression (Baron & Byrne, 1987). The definition of aggressive driving, as mentioned above, is about the former. Instrumental aggression includes all actions that an aggressor assumes will help him to move ahead by overcoming a frustrating obstacle. Accordingly, neither driving at high speed through a thrilling curve nor speeding in the absence of traffic are manifestations of aggressive driving, as none of these situations includes an obstacle (Shinar, 1998). In this definition, not only the presences of an obstacle, but also the judgement of others, who are (accidentally) affected by the behavior, play an important role. Thus, even if a driver does not perceive his behavior as aggressive, it is a manifestation of aggressive driving if others assess the behavior as inconsiderate, annoying, or dangerous. In contrast to instrumental aggression, hostile aggression does not solve a problem but makes the aggressor *feel better*. Shinar (1998) labels this kind of behavior as “road rage” and defines it as

> hostile behavior that are purposefully directed at other road users. These can be either driving behaviors (e.g., purposefully slowing a following vehicle or colliding with a lead vehicle) or non-driving behaviors (e.g., physically attacking someone). (p. 139)

Aggressive driving and road rage are treated as two distinct constructs that mainly differ in whether the aggressive action is at the expense of arbitrary and uninvolved others (aggressive driving) or purposefully directed at the source of frustration (road rage).

A more narrow definition of aggressive driving is provided by Doob and Gross (1968). The researchers use the latency to honk as an operational definition of the construct. In their experiments, participant drivers were frustrated by an experimenter driver in a high-status car (Chrysler) or low-status car (Ford or Rambler) honking at them. Doob and Gross (1968) assumed that the higher the status of honking driver (i.e., the aggressor), the more power he has to execute sanctions, which, in turn, prevents the target of aggression from responding in an aggressive manner. The aggressive response was operationalized as honking the horn against the aggressor. In this context, horn-honking is a type of instrumental behavior. Supporting their hypothesis, the researchers found out that low-status vehicles caused more horn-honking responses than high-status vehicles.

More generally, Dula and Geller (2003) define aggressive driving as "any behavior emitted by a driver while driving, that is intended to cause physical and/or psychological harm to any sentient being" (p. 559). The behavior might be directed at other motorists, passengers, or pedestrians and includes physical, verbal, and gestured aggression. In line with Shinar (1998), the authors emphasize that there are driving behaviors that are improperly labeled aggressive in the literature, above all, road rage and risky driving. While aggressive driving is characterized by the intent to harm, road rage strongly relates to the experience of negative emotions such as frustration, anger, sadness, dejection, or jealousy. Risky driving is linked to an individual's risk-taking tendencies and occurs without the experience of negative emotions or the intent to harm.

Aggressive driving can also be understood as "a pattern of unsafe driving behavior that puts the driver and/or others at risk" (Houston, Harris, & Norman, 2003, p. 270). Risk is operationalized by the occurrence of traffic accidents and violations. Again, this definition explicitly excludes the experience of negative emotions or the intent to harm. As a counterpart to unsafe driving, the authors define safe driving as "a pattern of safe driving behaviors that potentially protect the well-being of passengers, other drivers, and pedestrians, and that promotes effective cooperation with others in the driving environment" (Harris et al., 2014, p. 2).

Also, the National Highway Traffic Safety Administration distinguishes between aggressive driving and road rage. Aggressive driving is seen as a traffic offense, specified as "the operation of a motor vehicle in a manner which endangers or is likely to endanger people or property" (Stuster, 2004, p. 1). This definition refers to behaviors such as following too closely, driving at excessive speeds, weaving through traffic, and running a stop sign. Road rage is a criminal offense, more precise, "an assault with a motor vehicle or other dangerous weapon by the operator or passenger(s) of another motor vehicle or an assault precipitated by an incident that occurred on a roadway" (McCartt, Leaf, Witkowski, & Solomon, 2001, p. 1).

Finally, aggressive driving as an instrumental behavior needs to be distinguished from aggressive driving as a personality trait (Shinar, 1998). In this context, there is a close association between aggressive driving and trait driving anger. Based on the state-trait theory, it is assumed that drivers who have "a predisposition to experience more frequent and intense state anger across a large variety of driving situations" (Deffenbacher, Lynch, Oetting, & Yingling, 2001, p. 434) are more likely to behave aggressively in response to these situations. This can be explained by the fact that the emotional arousal has a significant impact on the aggressor's perception and performance so that situations are rated more frustrating than they are and that behavior is enacted more extremely than it should.

In conclusion, aggressive driving is understood as frustration-driven instrumental aggression and has to be distinguished from similar constructs such as road rage, risky and unsafe driving, or aggressive driving as a personality trait (Shinar, 1998). This type of aggression can not only be observed in violent, criminal, or mentally disturbed individuals but also in "normal" people, who behave aggressively from time to time while driving a car. Important to note, all definitions presented relate to intentional behavior and thus exclude aggression as a consequence of medical and drug-related influences, poor mental conditions, or human errors.

2.1.2 Model of Aggressive Driving

Besides a definition of aggressive driving, Shinar (1998) also developed a *multi-factor model of aggressive driving* that systematically describes the formation and change of aggression behind the wheel. The model is based on the *frustration-aggression hypothesis.* In the following sections, the frustration-aggression hypothesis and its evolution as well as the multi-factor model of aggressive driving are discussed.

Frustration-Aggression Hypothesis

The frustration-aggression hypothesis, also known as the frustration-aggression theory, was originally proposed by Dollard, Miller, and Doob (1939) and is one of the most influential explanations of aggressive behavior in social science (Breuer & Elson, 2017). In its original formulation (Figure 2.1.1), the hypothesis includes two very strict statements, stating that “aggression is *always* preceded by frustration” and “frustration *always* leads to aggression” (Dollard et al., 1939, p. 1). Frustration is defined as “an interference with the occurrence of an instigated goal-response at its proper time in the behavior sequence” (Dollard et al., 1939, p. 7). This definition negates the emotional experience associated with the interference and characterizes frustration by objective criteria, such as the personal relevance and desirability of the goal, the likelihood to achieve the goal, or the level of self-efficacy (Breuer & Elson, 2017). Aggression includes all behavior with the intent to harm a target, which can be the legitimate source of the frustration as well as something or someone not responsible for the interference, referring to the concept of displaced aggression (Breuer & Elson, 2017; Dollard et al., 1939).

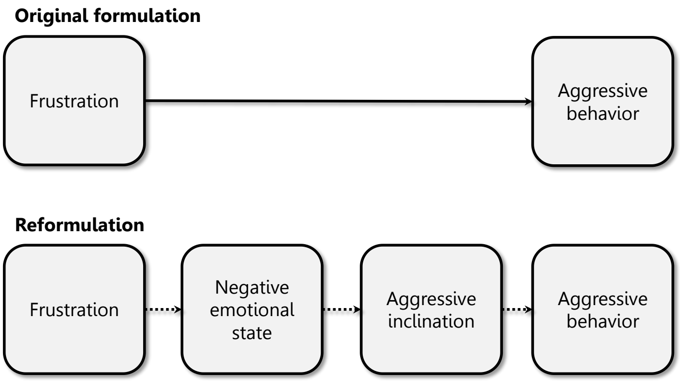


Figure 2.1.1. The original frustration-aggression hypothesis proposed by Dollard et al. (1939; top) and its reformulation proposed by Berkowitz (1989; bottom).

Despite its impact on the social sciences, the original frustration-aggression hypothesis has been strongly criticized due to its claimed universal validity, which is why it was later revised (Breuer & Elson, 2017). One of the most influential reformulations was coined by Berkowitz (1989). Most radical, he assumes that a goal-blocking stimulus only leads to aggression if it is accompanied by a negative emotional experience (Breuer & Elson, 2017). In doing so, Berkowitz (1989) completely redefined the understanding of frustration. Consequently, the relationship between frustration and aggression can be described as a multi-stage model, according to which frustration causes a negative emotional state, which, in turn, results in aggressive inclinations and subsequent aggressive behavior.

Multi-Factor Model of Aggressive Driving

Based on the frustration-aggression hypothesis, Shinar (1998) developed the multi-factor model of aggressive driving (Figure 2.1.2). At the core of this model, there is a situational source of frustration that prevents the driver from meeting his primary driving goal that is moving ahead with minimum delay (and some pleasure). A frustrating source might be another road user (e.g., slow vehicle ahead), an object (e.g., red traffic light), or an event (e.g., congestion). As these examples suggest, in the context of driving, most sources of frustration are associated with time pressure. However, an obstacle does not necessarily lead to aggression. Shinar (1998) illustrates this point as follows:

> A driver stopped at a signalized intersection behind another car. While the traffic light is red, the driver's desire to move ahead is frustrated, but the stopping of the car ahead is legitimate so no aggressive behavior ensues. If the lead driver does not proceed to move once the light changes to green then there is no legitimacy to the frustration, and the driver then has a disposition to honk. (p. 140)

This example shows that predisposing factors, including environmental factors (e.g., legitimacy, anonymity, and reduced communication between road users) and personality factors (e.g., extraversion, hostility, or other emotions), mediate a driver's aggressive disposition. If he does not have the mental, physical, or situational capability to enact this disposition— for example, due to cultural norms or legal restrictions— the aggression is enacted at other places or times, referring to the concept of displaced aggression. If the driver has the required capabilities, he determines a target at which the aggressive behavior is directed. This might be the perceived source of frustration, referring to hostile aggression or road rage, or arbitrary and uninvolved others, referring to instrumental aggression.

The major assumption proposed by Shinar (1998) is that aggressive driving can be mitigated in two ways. On the one side, behavior change interventions can have a *direct* impact on the behavior, such as legal measures. On the other side, aggressive driving can also be changed *indirectly* by preventing, manipulating, or removing the source of frustration. Shinar (1998) places special emphasis on the indirect route and the sources of frustration, assuming that situational conditions change over time rather than a driver's personality. He raises the questions of "why drivers in general are more aggressive now than before and what can be done (not necessarily to the drivers) to ameliorate the situation" (p. 142).

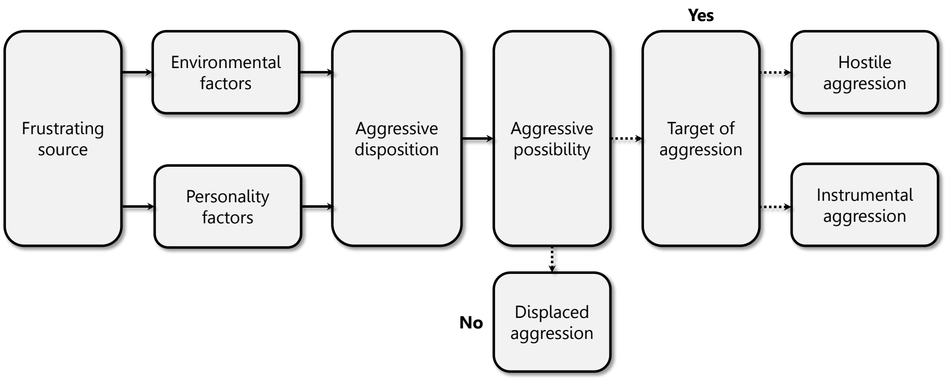


Figure 2.1.2. Multi-factor model of aggressive driving according to Shinar (1998).

2.1.3 Summary

Aggressive driving is an ambiguous construct in the scientific literature and everyday language that has to be differentiated from similar constructs such as road rage, risky, and unsafe driving, as well as aggressive driving as a personality trait. In the present work, aggressive driving is defined as "a syndrome of frustration-driven instrumental behaviors which are manifested in: (a) inconsiderateness toward or annoyance of other drivers [...] and (b) deliberate dangerous driving to save time at the expense of others [...]" (Shinar, 1998, p. 139). In line with this definition, Shinar (1998) introduced the multi-factor model of aggressive driving. According to this model, aggressive driving is a response to a source of frustration in the driving situation. Someone or something is frustrating when it blocks the driver's goals. This source of frustration is characterized by objective criteria as well as a negative emotional experience evoked by the blockage (Berkowitz, 1989; Dollard et al., 1939). The major conclusion of Shinar (1998) is that aggressive driving can be reduced directly by changing the driver's behavior, or indirectly by preventing, manipulating, or removing the source of frustration. Both ways to change aggressive driving constitute the underlying theoretical assumptions of this work. It has to be emphasized that this work does not strive to test these assumptions empirically. Rather, Shinar's (1998) model strengthens the present understanding of aggressive driving and indicates factors that have to be considered when developing a system to mitigate aggressive driving.

2.2 Persuasive Technology

It is clear that aggressive driving is an undesired behavior that should be changed. Whenever a party seeks to change the way another party acts, thinks, or feels, we are talking about influence (Miller, 2013). Persuasion is one form of influence that is characterized by the intent to influence and the voluntary nature of the intended change. Thus, unintended consequences are not considered persuasive, and persuasion clearly differs from behavioral changes resulting from coercion and deception, group pressure, or material inducement (Fogg, 1998; Simons & Jones, 2011). In the public and scientific context, persuasive attempts are mainly directed at behaviors that cause social problems. For example, persuasion "happens" when the health industry launches an anti-smoking campaign, a politician fights for voters, or a therapist counsels a criminal offender (Simons & Jones, 2011).

Human communication as well as HCI can have persuasive purposes. In the case of HCI, a person can be persuaded by another person using computer-mediated communication, speaking of computer-mediated persuasion, or by a system he is interacting with, referring to human-computer persuasion (Harjumaa & Oinas-Kukkonen, 2007). There is a growing number of interactive systems that are designed to influence user attitudes or behavior for the better in various domains such as health and wellness (Orji & Moffatt, 2018), physical activity (Matthews, Win, Oinas-Kukkonen, & Freeman, 2016), or sustainable mobility (Anagnostopoulou, Bothos, Magoutas, Schrammel, & Mentzas, 2016). These systems are a manifestation of Persuasive Technology that is defined as "computerized software or information systems designed to reinforce, change or shape attitudes or behaviors or both without using coercion or deception" (Oinas-Kukkonen & Harjumaa, 2008, p. 202). Accordingly, a persuasive system can have three potentially successful outcomes: reinforcing a present attitude or behavior, changing an individual's reaction to something or someone, or shaping a new attitudinal or behavioral pattern for a specific situation.

As a relatively young scientific discipline, Persuasive Technology benefits from what is known about how to change attitudes and behaviors from the behavioral and social sciences (Oinas-Kukkonen & Harjumaa, 2008; Simons & Jones, 2011). Thus, before the conceptual approaches of Persuasive Technology that underpin the present research are introduced, the traditional approaches they are built upon are investigated. An overview of the reviewed approaches and their interplay is shown in Figure 2.2.1.

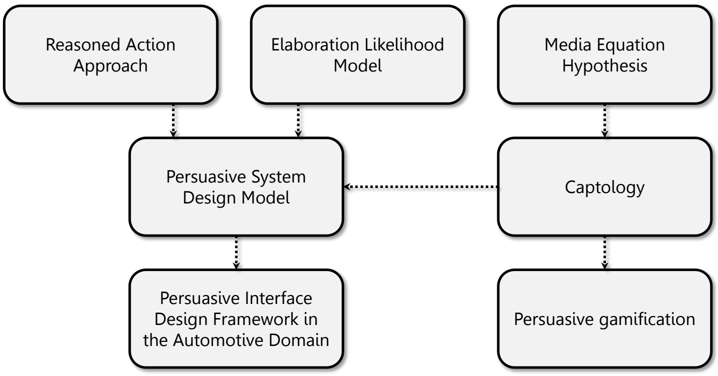


Figure 2.2.1. Theoretical and conceptual approaches reviewed in this work.

2.2.1 Behavior Change in Social Psychology

Models, approaches, and theories from social psychology prepared the ground for Persuasive Technology. Among these, especially (i) the *reasoned action approach* (Fishbein & Ajzen, 2010) and (ii) the *elaboration likelihood model* (Petty & Cacioppo, 1986) provided important theoretical foundations. Both are detailed below.

Reasoned Action Approach

In 1967, Fishbein claimed that behavior follows intentions, which are formed by the attitude toward the behavior and perceived norms (Fishbein, 1967). Refining this relationship by considering the influence of individual differences on intentions, Fishbein and Ajzen (1975) introduced the *theory of reasoned action.* Later on, Ajzen (1985) added the construct of perceived behavioral control as a predictor of both intention and behavior, calling his extension the *theory of planned behavior.* In its most recent incarnation, the interplay between intentions, attitude, and behavior is described with the reasoned action approach (Fishbein & Ajzen, 2010).

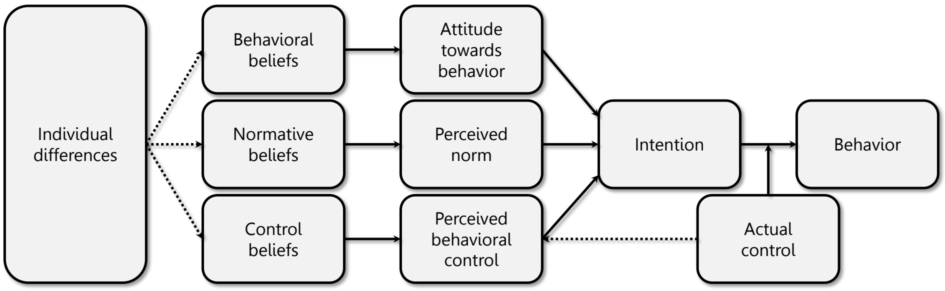


Figure 2.2.2. Reasoned action approach according to Fishbein and Ajzen (2010).

According to the reasoned action approach, human social behavior is based on the behavioral, normative, and control beliefs an individual has about the behavior in question (Figure 2.2.2). These beliefs are acquired through past experiences and influenced by individual differences, such as demographic characteristics, personality traits, or mental and physical conditions. Behavioral beliefs relate to the positive and negative consequences the individual expects from the enactment of the behavior, which, in turn, form his attitude toward the behavior. Normative beliefs are based on what the individual believes that relevant others think of the behavior. These beliefs determine the individual's perceived norms, which are experienced as social pressure to perform (or not perform) the behavior. Finally, control beliefs refer to the personal and situational capability to perform the behavior. Depending on whether the conditions are facilitating or inhibiting, they lead to a high or low level of perceived behavioral control. In combination, the attitude toward the behavior, the perceived norms, and the perceived behavioral control emerge in the behavioral intention to perform the behavior. In the last instance, the actual control, which is determined by mental, physical, and environmental constraints, moderates whether the behavior is enacted or not (Fishbein & Ajzen, 2010).

In Persuasive Technology, the reasoned action approach and its derivatives explain how technology can change behavior by applying mechanisms known from social psychology, such as expectancy-value models and social dynamics.

Elaboration Likelihood Model

The elaboration likelihood model (ELM; Petty & Cacioppo, 1986) is a process model for persuasion that originated in social psychology as a type of dual-process theory. Dual-process theories, in general, propose that stimuli can be processed in two different ways that are usually associated with a higher or lower level of human thinking. Dual-process theories can be found everywhere in psychology, economics, and sociology. Depending on the discipline, different labels are used to describe the dichotomy of processing, differentiating between automatic and controlled, direct and indirect, explicit and implicit, heuristic and analytic, or unconscious and conscious processes (Frankish, 2010; Gawronski & Creighton, 2013).

The ELM proposes two distinct routes to process a persuasive message (Figure 2.2.3): central or peripheral (Petty & Cacioppo, 1986). Which route of persuasion the persuadee takes, depends on his motivation and ability to elaborate the arguments of the message, which constitutes the elaboration likelihood. The individual's motivation and ability are determined by current conditions such as the personal relevance of the message (motivation) or the availability of cognitive resources (ability). If the elaboration likelihood is high, the central route is used. In this route, information is systematically processed, which results in stable changes in behavior or attitude. If the elaboration likelihood is low, the individual takes the peripheral route. By this, the processing of the message mainly relies on heuristics and other cognitive shortcuts that are triggered by simple environmental cues (e.g., an attractive source). In contrast to the central route, the peripheral route leads to rather unstable changes (Petty & Cacioppo, 1986).

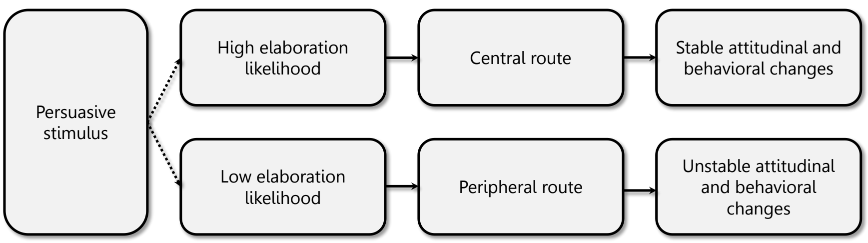


Figure 2.2.3. Elaboration likelihood model according to Petty and Cacioppo (1986).

The ELM provides a relevant theoretical foundation for many modern Persuasive Technology approaches. It helps to understand a user's motivation and ability to process a persuasive message and to determine the proper information he needs for this purpose.

2.2.2 Behavior Change through Persuasive Technology

Although traditional approaches from social psychology have affected the study of persuasion in systems, they are not directly applicable in HCI. Therefore, individual approaches, frameworks, and models have emerged in Persuasive Technology. Two of the most common ones are (i) the work of Fogg, summarized under the term *Captology* (Fogg, 1998), and (ii) the *persuasive system design model* (Oinas-Kukkonen & Harjumaa, 2009). Based on these approaches, domain-specific derivatives and new directions were developed, such as (iii) the *persuasive interface design framework in the automotive domain* (Paraschivoiu, Meschtscherjakov, Gärtner, & Sypniewski, 2019), and (iv) the concept of *Gamification* as a persuasive approach.

Captology

According to Fogg (1998), "a persuasive computer is an interactive technology that attempts to change attitudes or behaviors in some way" (p. 225). Following this definition, he introduced the term Captology as "the study of computers as persuasive technologies" (Fogg, 1998, p. 225). Captology combines many different ideas from media psychology, above all, the *media equation hypothesis* that assumes that people treat computers, television, and other new media like human beings (Reeves & Nass, 1996). Moreover, Captology incorporates basic principles of social psychology, such as the use of praise, the enhancement of affiliation and similarity, the stimulation of personality traits, or the principle of reciprocity (Atkinson, 2006). In one of his first papers on Captology, Fogg (1998) proposes five perspectives on persuasive computers that essentially inspired the Persuasive Technology community: (i) definition of persuasive computers, (ii) functional view of persuasive computers, (iii) levels of analysis for Captology, (iv) design space for Captology, (v) ethics of computers that persuade.

(i) **Definition of persuasive computers:** Fogg (1998) defines persuasive computers as "an interactive technology that attempts to change attitudes or behaviors in some way" (p. 225). This definition emphasizes the *intent* to change as a central characteristic of Captology. There are three types of persuasive intent, each referring to the force that triggers the change: endogenous, exogenous, and autogenous. Accordingly, the force can be the system designer (endogenous), the person who distributes the system (exogenous), or the individual himself (autogenous).

Functional view of persuasive computers: the second perspective includes the fundamental framework of Captology, the *functional triad*. The framework describes the different roles a persuasive computer can have from the perspective of its user: tool, medium, or social actor. Tools increase a person's ability to do things or makes things easier to do. Fogg (2003) defined seven types of persuasive tools, each associated with a persuasive principle that simplifies a task: (i) reduction (narrowing complex activities to simple steps), (ii) tunneling (guiding through a sequence of actions), (iii) tailoring (providing relevant and personalized information), (iv) suggestion (providing advice about appropriate behavior), (v) self-monitoring (providing information on performance and progress), (vi) surveillance (others monitoring an individual's performance and progress), and (vii) conditioning (using positive reinforcement). As a medium, the computer uses the persuasive power of simulations. There are three types of simulations that foster behavior change (Fogg, Cuellar, & Danielson, 2002): simulated cause-and-effect scenarios that show the consequences of a certain behavior (e.g., smartphone apps showing the future self), simulated environments that expose users to new surroundings (e.g., virtual reality treatments to reduce phobias), or simulated objects from real life (e.g., virtual pets). As a social actor, the computer attempts to create a social relationship with the user to provide social support, be a role model, or leverage social norms (Fogg et al., 2002). In order to be perceived as social, the computer needs to embody animate characteristics (e.g., physical features or emotions), play animate roles (e.g., assistant or pet), or adapt social rules (e.g., greetings or apologies).

(ii) **Levels of analysis for Captology:** the third perspective describes the different levels of analyzing both computer use and change processes. Beyond the individual level, persuasive computers can be analyzed on an intra-individual, interindividual (e.g., dyads, couples, or friends), family, group, organizational, community, or societal level.

(iii) **Design space for Captology:** the fourth perspective outlines the design space for Captology by exemplifying issues in domains such as safety, environment, or personal management. Today, there are far more issues and domains than proposed in the earlier works of Fogg (1998), such as disease management (e.g., managing diabetes better), community involvement and activism (e.g., volunteering at a community center), or commerce (e.g., buying a certain product; Fogg et al., 2002).

(iv) **Ethics of computers that persuade**: the fifth and final perspective addresses the ethics of persuasive computers. In general, ethical problems arise when the intent of a persuasive system interferes with user intent. This perspective is not deepened here. However, other authors have extensively discussed the ethical shortcomings of Captology (Atkinson, 2006).

Although the work of Fogg, especially the functional triad, pioneered Persuasive Technology, its design focus and the omission of significant user involvement is regarded as a serious oversight (Atkinson, 2006).

Persuasive Systems Design Model

One of the most recent and relevant models in Persuasive Technology is the persuasive systems design model (PSDM) proposed by Oinas-Kukkonen and Harjumaa (2009). Providing the definition of Persuasive Technology for the present work, the authors define persuasive systems as “computerized software or information systems designed to reinforce, change or shape attitudes or behaviors or both without using coercion or deception” (Oinas-Kukkonen & Harjumaa, 2008, p. 202). In contrast to Captology, the PSDM not only helps to systematically understand, design, and evaluate Persuasive Technology but also specifies what kind of content and functionality the final system should entail. As depicted in Figure 2.2.4, the PSDM describes the study of Persuasive Technology as a three-step process. The process starts with (i) the understanding of the key issues behind the persuasive system, continues with (ii) the analysis of the persuasion context, and concludes with (iii) the design (or evaluation) of future (or present) system requirements (Oinas-Kukkonen & Harjumaa, 2009).

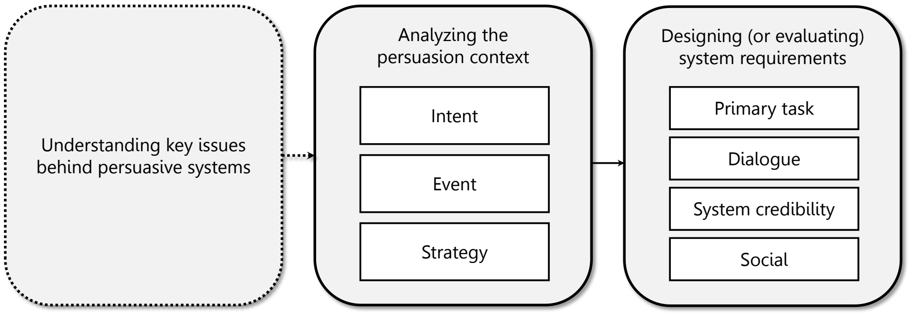


Figure 2.2.4. Persuasive systems design model according to Oinas-Kukkonen and Harjumaa (2009).

The key issues are manifested in seven postulates, which a system designer needs to comply with when developing or evaluating a persuasive system (Oinas-Kukkonen & Harjumaa, 2009, p. 487). (i) First of all, "information technology is always on" so that persuasion is an on-going process. (ii) Second, "people like their views about the world to be organized and consistent." It is assumed that the commitment to the persuasive system results from regular and meaningful interactions and the more committed a user is to a system the more likely he will be persuaded by it. (iii) Referring to the ELM (Petty & Cacioppo, 1986), the third postulate implies that "direct and indirect routes are key persuasion strategies." Both routes can be supported by system features that trigger either the deeper evaluation of a message or cognitive shortcuts. (iv) According to the fourth postulate, stating that "persuasion is often incremental," it is easier to initiate a behavioral change by enabling the individual to make single steps toward the target behavior. (v) The fifth postulate claims that "persuasion through persuasive systems should always be open," implying that the designer's intent has to be clear. (vi) Sixth, "persuasive systems should aim at unobtrusiveness" to avoid interferences with the primary task. (vii) Finally, it is claimed that "persuasive systems should aim at being both useful and easy to use" to satisfy user needs.

In the second step of the PSDM, the persuasion context is analyzed, including the intent of persuasion, the persuasion event, and the persuasive strategy. Considering the intent, the persuader and the change type are distinguished. As described by Fogg (1998), the persuader can be endogenous, exogenous, or autogenous, and he can attempt to change attitudes or behavior. The persuasion event includes the use context (i.e., features of the problem domain in which the system is used), the user (i.e., individual differences), and the technology context (i.e., strengths, weaknesses, risks, and opportunities of the technology behind the system). Finally, the strategy refers to the content and format of the persuasive message and the route that the persuadee takes according to the ELM (Petty & Cacioppo, 1986). The decision about whether a user chooses the central or peripheral route can be influenced by using proper system features such as simple cues to handle the abundance of information in the peripheral route (Oinas-Kukkonen & Harjumaa, 2009).

In the last step, the PSDM suggests 28 persuasive principles that might motivate attitudinal or behavioral changes and that can be seen as system requirements of effective Persuasive Technology. The collection of principles is inspired by Fogg (2003) and serves four categories: primary task, dialogue, credibility, and social support. Primary task support principles help the user to perform a task and relate to functional parts of the system (e.g., self-monitoring to keep track of one's performance and progress). Dialogue support principles foster the interaction between the user and the system (e.g., reminders of the target behavior). Credibility support principles propose design elements to increase the system's credibility (e.g., a system that incorporates expertise). Finally, social support principles leverage social influence, for example, by triggering the human need for competition (Oinas-Kukkonen & Harjumaa, 2009).

Like the work of Fogg (2003), the PSDM is a generic approach that is suitable for a variety of domains. However, there are persuasive contexts with special requirements, such as driving a car, that require an adapted approach. One such approach is the persuasive interface design framework in the automotive domain (Paraschivoiu et al., 2019), which is described in the following section.

Persuasive Interface Design in the Automotive Domain Framework

Based on the PSDM, the persuasive interface design framework in the automotive domain (PIDAF; Paraschivoiu et al., 2019) is a framework to support designers in designing automotive interfaces, generating system ideas, or identifying blind spots for research and development. For this, the four-level framework provides choices (i) to define the intent of the system, (ii) to determine relevant cues and (iii) persuasive principles, and (iv) to specify the final design of the system (Figure 2.2.5).

The intent is defined by the aim of the system and the domain in which it is used. In the automotive domain, persuasion can be aimed at changing attitudes or behaviors that are associated with safe driving, ecological driving, or another driving-related domain.

Cues are system features that trigger the intended change. They can be specified by four features: psychological cues, verbal cues, social dynamics, and Gamification. Psychological cues differ in whether they are consciously or unconsciously perceived and processed by the driver. Verbal cues refer to the use of language, both written and spoken. Given different types of social dynamics, the interface can be designed as a single or multi-user solution and it can trigger competition or cooperation. Gamification refers to the implementation of design elements used in games (Deterding, Dixon, Khaled, & Nacke, 2011). The idea of using the principle of Gamification for the purpose of persuasion is deepened in the following section *2.2.2 Behavior Change through Persuasive Technology: Gamification as a Persuasive Approach.*

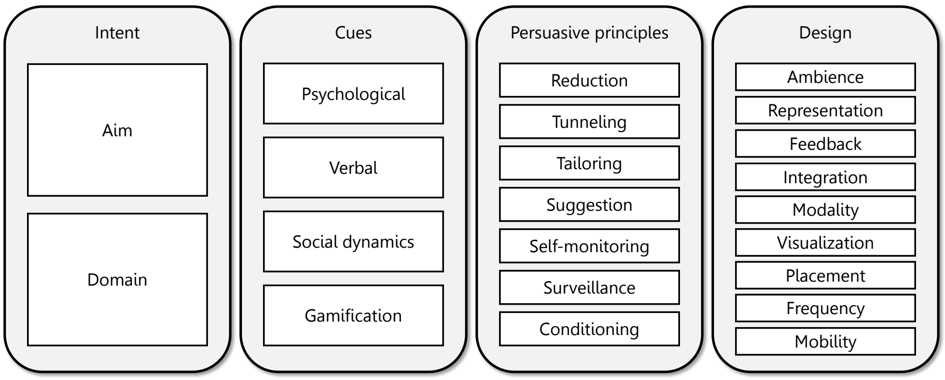


Figure 2.2.5. Persuasive interface design framework in the automotive domain according to Paraschivoiu et al. (2019).

Principles are universal rules that guide human behavior and that can be translated into system specifications. Here, the PIDAF adapts the seven persuasive principles of Fogg (2003), i.e., reduction, tunneling, tailoring, suggestion, self-monitoring, surveillance, and conditioning. As no principle alone explains what causes a behavior change, a designer might choose several that are tailored to the system in question.

The last level of the PIDAF describes nine design options that relate to potential design elements inside and outside the car. The options ambience (peripheral or focal), integration (additional or augment existing interfaces), modality (visual, haptic, and/or auditory), placement (inside or outside the car), and mobility (mobile or fixed) relate to the physical configurations of the interface. In contrast, representation (concrete or metaphorical), feedback (immediate or delayed), visualization (discrete or continuous), and frequency (during the action, as a summary, or beforehand) are option that help to determine the content of the final system.

The PIDAF goes beyond the design focus of the functional triad and extends the PSDM by providing a model tailored to the context of driving and the special system requirements it entails.

Gamification as a Persuasive Approach

Taking up the idea of using Gamification for the purpose of persuasion, this section examines the principle of Gamification as an approach to Persuasive Technology. The most widely used definition of Gamification is "the use of game design elements in non-game contexts" (Deterding et al., 2011, p. 9). Gamification elements can be artefactual or social in nature, including avatars, 3D-sceneries, narratives, feedback, reputations, points, ranks and levels, marketplaces and economies, competition and cooperation, or time pressure (Deterding et al., 2011). For instance, the bonus point system of a supermarket or the fitness app that shows us the progress of our friends is gamified systems. These examples demonstrate the variety of contexts in which Gamification is used, ranging across productivity, finance, health, education, sustainability, news, and media. Regardless of the use case, the goal of Gamification is to motivate people to change behaviors, develop skills and acquire knowledge, or drive innovation while having fun and playful experiences (Biran, 2014; Ferrara, 2013). This goal differentiates gamified systems from games as a medium for entertainment and leads over to persuasion (Llagostera, 2012; Werbach, 2015). The parallels between Gamification and Persuasive Technology are demonstrated with the work of Llagostera (2012), who contrasts different Gamification elements with the persuasive principles proposed by Fogg (2003). For example, most gamified activities have to be carried out step-by-step in order to reach the intended outcome, which corresponds to the principle of tunneling. Many gamified systems track activity-related data and provide them to the user, which can be seen as a form of self-monitoring and surveillance. Finally, most gamified systems use feedback and positive rewards, such as virtual badges, levels, achievements, or virtual points, which is a form of conditioning.

Even if there is theoretical evidence that Gamification can be seen as a sub-field of Persuasive Technology, there is no approach that provides guidance on how Gamification elements can be used to unfold their persuasive power. Nevertheless, Gamification is considered an effective tool for behavior change and an inspiring approach within the present work.

2.2.3 Summary

Persuasive Technology is defined as "computerized software or information systems designed to reinforce, change or shape attitudes or behaviors or both without using coercion or deception" (Oinas-Kukkonen & Harjumaa, 2008, p. 202). Besides this definition, this section has presented different approaches, frameworks, and models for designing and evaluating persuasive systems, including the theoretical foundations they are built upon. Most important for the present research, the persuasive interface design framework in the automotive domain (PIDAF; Paraschivoiu et al., 2019), and the idea of Gamification as a persuasive approach have been introduced. The PIDAF constitutes a framework to support designers in designing persuasive in-car interfaces. Gamification provides a new perspective on persuasion through systems by considering the use of game design elements to motivate changes in behavior.

2.3 Related Work

The following sections introduce relevant application examples and scientific studies aimed at changing aggressive driving and beyond. This review includes both technical and non-technical solutions, which are broken down into therapeutic interventions, environmental interventions, and in-car interfaces.

2.3.1 Therapeutic Interventions

Therapeutic interventions attempt to directly change a driver's behavior using treatment methods known from psychotherapy. As one of the first, Galovski and Blanchard (2002) developed a cognitive-behavioral program for aggressive drivers. The program lasted several weeks and consists of practices on relaxation techniques (e.g., progressive muscle relaxation), cognitive strategies (e.g., identifying and addressing personal triggers and consequences of aggressive driving), coping skills (e.g., establishing a hierarchical list of provoking driving situations and examining how to deal with them), and educational lessons about the impact of aggressive driving. In a controlled evaluation with 20 court-mandated and eight self-identified aggressive drivers, the authors investigated the effect of the treatment on aggressive driving. They compared the treated groups with a control group that only monitored their aggressive symptoms. The effect on aggressive driving was assessed through daily diaries and standardized self-reports (e.g., overall driving anger, trait anger, angry reaction). As a result, the treated groups improved by 50 percent, while the monitoring group did not improve at all.

Deffenbacher (2016) reviewed work on interventions to lower aggression in angry drivers. He grouped the identified measures into cognitive interventions, relaxation interventions, and behavioral interventions and found empirical support for each of the categories as well as their combination. Cognitive interventions aim to change the cognitive patterns that underlie the aggressive behavior (e.g., shifting attention to other topics). Here, the first step is to support clients in becoming more aware of the stimulus that triggered the aggression. Relaxation interventions attempt to stimulate the emotional-physiological arousal associated with the aggressive behavior by conveying relaxation and coping skills that lower an individual’s arousal level (e.g., focal tension exercises). Finally, behavioral interventions are aimed at changing dysfunctional ways of dealing with aggression, for example, by avoiding known sources of aggression.

Grounded in the field of emotion regulation, Popuşoi and Holman (2016) examined the moderating effect of different emotion regulation strategies on the relation between driving anger and aggressive tendencies. The authors considered three different types of emotion regulation strategies: cognitive reappraisal, expressive suppression, and experiential avoidance. In a study with 314 drivers, they revealed a moderation effect of expressive suppression on the relation between driving anger and aggressive driving, suggesting that drivers, who tend to suppress their emotions, behave more aggressively when experiencing driving anger.

2.3.2 Environmental Interventions

Environmental interventions are aimed at manipulating factors in the driving environment and, therefore, have an indirect effect on driving behavior. The potential of environmental interventions can be appreciated from a study of Retting and Greene (1997), who investigated the influence of traffic signal timing on red-light violations. Their focus was on crashes that are caused by vehicles entering an intersection after the onset of a red light. If the violating vehicle is still at the intersection when the light of the crossing road users turns green, a traffic conflicts occurs. As assumed by the authors, this kind of traffic violation is affected by the duration of the clearance interval that is composed of the yellow and red periods of the traffic signal. In a field study, Retting and Greene (1997) observed ten intersections to collect data on the traffic signal timings, the number of vehicles entering on a red light, and the number of vehicles exiting the intersection after the onset of a conflicting green light. The observations revealed that red light violations were reduced when the clearance intervals were increased, subsequently reducing the risk of intersectional conflicts.

Likewise, the visual content of the roadside, such as billboards and vegetation, can be manipulated. For instance, Cackowski and Nasar (2003) revealed that roadside vegetation can have restorative effects in reducing frustration while driving. In a laboratory study, 106 participants watched one of three videotapes of highway drives that varied in the relative amount of roadside vegetation and man-made material. The video with the highest amount of vegetation included heavy roadside vegetation that completely blocked the view of artificial structures. The second video showed some vegetation and parkway elements, such as few signs or telephone poles. The last video was about a highway drive with road strip malls, commercial signs, and telephone poles and minimum vegetation along the road side. Before and after video exposure, participants were asked about their frustration tolerance and state driving anger. No effect could be shown for anger, but the frustration tolerance significantly increased for videos with more vegetation.

Providing an example of roadside billboards, Figure 2.3.1 depicts a campaign of the German Federal Ministry of Transport and Digital Infrastructure (*Ger.* Bundesministerium für Verkehr und digitale Infrastruktur), counteracting aggressive driving behaviors such as speeding or tailgating. Most roadside billboards are educational in nature and attempt to change the way a person thinks about a certain behavior. However, billboards themselves can also be a source of frustration if they entail hostile or stressful content (Wickens, Mann, & Wiesenthal, 2013).

Figure 2.3.1. Roadside billboard of a German speed prevention campaign (Bundesministerium für Verkehr und digitale Infrastruktur, 2020).

Tuner, Layton, and Simons (1975) examined the effect of weapons as an aggressive trigger provided by other road users. In one of their field studies with 200 participants, they used a pick-up truck that purposely remained stalled at a green traffic light to block road users trapped behind it. The truck was visibly equipped with either (i) a rifle in a gun rack and a bumper sticker saying "vengeance," (ii) a rifle with a gun and bumper sticker saying "friend," or (iii) no rifle and no sticker. The sticker was meant to influence the rifle's meaning, assuming that the weapon in combination with the "vengeance" sticker would cause more horn-honking responses than the rifle combined with the "friend" sticker, or the control condition. Supporting this assumption, both the presence of the rifle as well as the rifle combined with the "vengeance" sticker resulted in higher rates of horn-honking against the truck compared to the control condition.

Finally, the anonymity between road users is also an environmental factor of aggression behind the wheel that is widely discussed. Anonymity results from the temporal and physical remoteness on the road that occurs because road users communicate over large distances and through the physical body of the car (Parkinson, 2008). Ellison-Potter, Bell, and Deffenbacher (2001) examined the effects of driving anger trait, aggressive stimuli, and anonymity on aggressive driving. In a driving simulator study, 146 high-anger and 143 low-anger drivers were randomly assigned to one of four experimental conditions of a 2x2 study design: anonymous vs. identifiable and exposure to an aggressive stimulus vs. neutral stimulus. Aggressive driving measures included different behaviors such as red light runs, speeding, and collisions with motorists and pedestrians. As a means of manipulating anonymity, participants were told to imagine either that the other road users in the simulation know who they are or not. It was shown that participants drove more aggressively when they were anonymous and exposed to an aggressive stimulus. No effects were found for trait driving anger.

2.3.3 In-car Interfaces

Like the physical driving environment, also the vehicle interior, especially the in-car interfaces, can be manipulated for the purpose of changing driving behavior. This group of interventions includes feedback-based interfaces, conversational agents, physiological interfaces, and social interfaces.

Feedback-based Systems

Today, there are already several commercial in-car interfaces to support a more environmentally friendly driving style. In principle, these systems provide the driver with feedback on his performance with a special focus on driving behavior that determines the fuel consumption, such as acceleration, braking, and gear shifting. As shown in Figure 2.3.2, these systems use different visualizations of the feedback, including abstract designs (e.g., natural animations) or discrete designs (e.g., scores and progress bars).

Meschtscherjakov, Wilfinger, Scherndl, and Tscheligi (2009) investigated the acceptance of five interface concepts for a more ecological driving style in an online survey with 57 respondents. Four concepts were feedback-based: (i) the eco accelerator pedal that exerts pressure against the driver's foot when wasteful acceleration is detected, (ii) the eco speedometer that changes its color in accordance with the fuel consumption, (iii) the eco display that visualizes the fuel consumption through the animation of growing or vanishing leaves, and (iv) the eco advisor that gives verbal hints to foster fuel-efficient driving. In addition, (v) a system that reduces fuel consumption by adjusting vehicle parameters automatically was presented. Overall, the acceptance, as well as the usefulness, was high for all systems.

Figure 2.3.2. In-car interfaces to support ecological driving developed by Mercedes-Benz (top; 2020), Ford (middle; 2016), and Renault (bottom; 2019).

Likewise, feedback systems for less aggressive driving have been developed. However, they have not yet been used commercially. For example, CarCoach is a system that promotes polite and effective driving (Arroyo, Sullivan, & Selker, 2006). The system monitors selected driving parameters (i.e., rpm, speed, throttle position, brake pressure and position, steering position angle, cup holder state, and on-board system status), makes decisions about driving successes and mistakes, and gives an auditory and a tactile feedback when a success or mistake is detected. Auditory reminders are given by a female voice in the form of a negative warning (e.g., “please signal on”) or a positive message (“thank you for signaling”), respectively. Tactile reminders are transferred via steering wheel or pedal vibrations. The authors validated their system in a real-world driving study with 18 participants, testing the effects of the feedback type (positive vs. negative) and scheduling schemes (no feedback, continuous feedback, scheduled feedback) on driving performance and frustration. The results indicated that positive feedback increased performance when presented continuously, but not in the scheduled condition. In contrast, negative feedback generally decreased performance, both when being presented continuously as well as scheduled.

In another study, Adell, Várhelyi, and Hjälmdahl (2008) equipped the personal vehicles of 22 participants with a warning system that instantly gave an acoustic signal and a flashing red light when the speed limit was exceeded. However, although the researchers showed that the system reduced speeding violations, the participants rated the system as annoying and irritating due to its acoustic nature.

Conversational Agents

Conversational in-car agents interact with the driver and passengers using natural language. In order to improve the driver-vehicle communication, they can also have a visual representation, such as an anthropomorphic avatar or an abstract icon (Figure 2.3.3), which can (Görtz, Mandl, Arévalo, & Womser-Hacker, 2007).

Figure 2.3.3. Examples of anthropomorphic (left; Charamel, 2019) and abstract (right; BMW, 2020) representations of in-car agents.

Conversational agents mainly make use of content and prosodic features to change a driver's behavior (Krahmer & Swerts, 2009). For example, Jonsson et al. (2004) investigated the impact of a virtual passenger on the driving performance and likability of the car in a driving simulator study with 36 participants. While driving, three types of verbal warnings about the driver's performance were given: driver-blame prompts (e.g., "*you* are driving too fast"), we-blame prompts (e.g., "*we* are driving too fast"), and environment-blame prompts ("the *road* is easy to handle at low speeds"). Each participant completed a test drive in all three conditions, while their attention was measured. To indicate their attention, they were asked to say the word "honk" as soon as they heard a honk, and the reaction time was measured. The results indicate that warnings that blame the environment work best; they increased the participants' attention as well as the likability of the car. In a simulator study with 109 participants, Nakagawa, Park, Ueda, and Ono (2017) showed that the presence of a conversational agent that praises or encourages the driver after mastering a hazardous event (instead of just providing practically relevant information) leads to a more cautious driving style. Providing an example of prosodic manipulation, Nass et al. (2005) paired the emotional tone of the car voice (energetic vs. subdued) with the emotional state of the driver (happy or upset). They evaluated their system concept in a simulator study with 40 drivers. When both factors match, drivers have fewer accidents, are more attentive, and talk more to the car.

Physiological Interfaces

Physiological interfaces are mainly aimed at detecting and leveraging physiological stress while driving, which is a predisposing factor of aggressive driving. As known from emotion regulation research, people under the influence of strong (negative) emotions can be helped to manage these states by becoming aware of them. Thus, Hernandez et al. (2014) designed (but did not evaluate) different solutions to visualize a driver's affective state using air conditioning, ambient lighting, or music. For example, the reflective dashboard changes its color in reference to the physiological changes of the driver (Figure 2.3.4). Green indicates a more relaxed state, whereas red is associated with stress.

Likewise, Braun, Chadowitz, and Alt (2019) proposed three in-car ideas to visualize the driver's state based on insights from focus groups: the Gamification concept, the Notification concept, and the Quantified Self concept. The Gamification concept attempts to detect and display the current state of the car (i.e., car condition and fuel consumption) and the driver (i.e., driver health and driver fun) using a scale-like representation. The concept of Notification responds to negative driver emotions using a minimalistic background animation combined with text notifications. Finally, the Quantified Self interface is inspired by modern fitness tracking apps, displaying two circular diagrams that visualize the driver's vital and emotional state. The user experience of the concepts was evaluated in a driving simulator study with 328 participants, each assessing one of the concepts. Although participants generally preferred the concept of the quantified self, it was shown that age, driving experience, and personality traits have an impact on personal preferences.

Figure 2.3.4. Reflective dashboard developed by Hernandez et al. (2014).

Lastly, breathing practices known from psychotherapy inspired the design of the in-car interventions to manage stress. For instance, Paredes et al. (2018) developed a system to achieve a slower breathing rate. The system guides the driver to inhale and exhale via vibrations in the car seat and spoken audio commands. The results of a laboratory experiment with 24 participants showed that both the haptic and the voice guidance system reduced the breathing rate. However, most people preferred the haptic solution because it was easier to understand, less distracting, and easier to engage with and disengage from.

Social Interfaces

Social interfaces enable the interaction between road users. In doing so, they remove the anonymity on the road. Wang, Zeng, Carley, and Mao (2015) gave drivers the possibility to commend others' driving behaviors by sending them a "like" or "dislike" that was displayed in their cars. The authors evaluated their system in a simulator study. During the test drive, 18 participants fed back the behavior of other drivers in the simulation and received feedback on their own driving style. "Dislike" behaviors were, for example, tailgating, cutting others off the road, or not using turn signals. As a result, the feedback caused participants to drive more social, i.e., they showed fewer traffic violations.

Soroa, Wollstädterb, and Rakotonirainya (2014) presented six in-car applications that promoted cooperative driving. Their ideas include socially inspired Gamification elements. For example, they introduced the idea of driving behavior badges that can be earned by other drivers in the community voting for the driver's performance. Other application concepts are based on the idea of chatting with each other or to share different kinds of information, such as music, emotions, or snapshots of the current driving situation. The applications were prototypically implemented into a computer-based driving simulator and discussed by nine participants. In particular, the ideas of sharing music and snapshots were assumed to foster sympathy as well as intimacy and prevent conflicts between road users.

2.3.4 Summary

This review disclosed a wide range of existing scientific and commercial interventions aimed at improving driving behavior, such as ecological, safe, or stress-free driving. The interventions can be differentiated into therapeutic interventions, environmental interventions, and in-car interfaces. Although each category provides interesting and inspiring examples, they all have their limitations. Therapeutic interventions are primarily aimed at extreme cases, such as hostile and criminal drivers, and therefore mainly refer to the definition of road rage. Given the environmental interventions, environmental aspects that trigger negative emotions are costly to affect or cannot be manipulated at all, such as rush hours or the weather. In-car interfaces are easier to manipulate. However, it is assumed that individual differences are a decisive factor for the acceptance and effectiveness of such systems so that there is no solution to mitigate aggressive driving that fits all. Maybe that is why there are few commercial solutions.

2.4 Interim Conclusion

Based on the theoretical background, the initial research questions of this thesis are derived. Moreover, the research and design activities that are necessary to achieve the research goal of developing a Persuasive Technology solution to mitigate aggressive driving are planned. The empirical part of this work is guided by the *human-centered design* (HCD) approach. Before the initial research questions are presented, the idea and benefits of HCD are introduced.

2.4.1 Human-centered Design Approach

HCD is a broad term that describes the process of designing a system by involving the end-users throughout this process. In doing so, the most *usable* solution is expected to be achieved. For this, HCD activities adhere to the following principles: (i) involving the user to understand his needs and the context in which the system will be used, (ii) determining the appropriate allocation of functions between the user and the final system, (iii) conducting research and design activities iteratively, and (iv) working in multi-disciplinary teams (International Organization for Standardization, 2019).

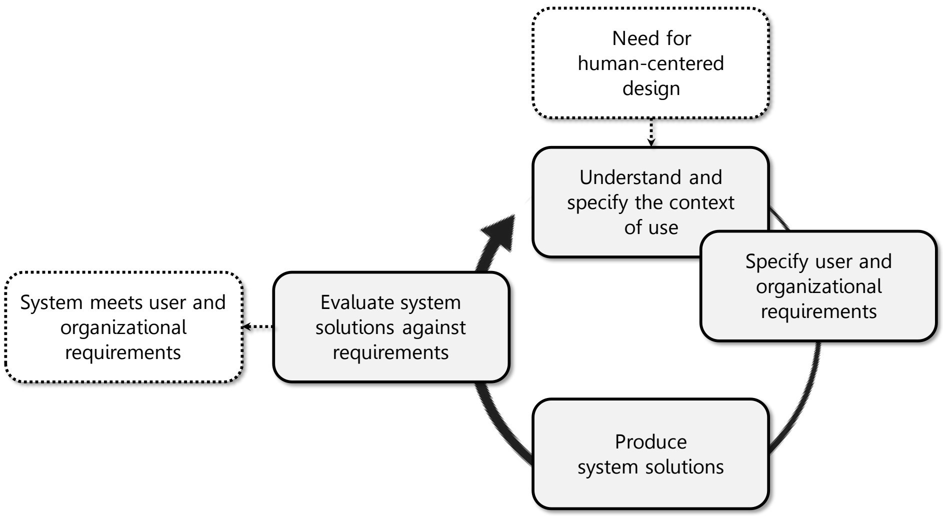


Figure 2.4.1. Human-centered design process adapted from ISO 9241-210 (International Organization for Standardization, 2019).

A variety of approaches have been developed to support HCD, such as participatory design, ethnography, the lead user approach, contextual design, co-design, or empathic design (Steen, 2011). Most approaches are based on the ISO norm 9241-210 that standardizes the HCD processes for interactive systems (International Organization for Standardization, 2019). Accordingly, the ideal HCD process is an iterative cycle that includes four consecutive steps (Figure 2.4.1): (i) understand and specify the context of use, (ii) specify user and organizational requirements, (iii) produce system solutions, and (iv) evaluate these against the identified requirements. This process should be initiated when the need for a human-centered solution is given, for example, when there is a concrete design problem or an initial concept for a product or service.

The context includes relevant characteristics of the intended user and relevant stakeholders, the task the system is used for, and the physical and social conditions of the environment in which the system is used. User and organizational requirements mainly refer to the usability of a product. Usable products are characterized as effective, efficient, and easy to use. Moreover, they are appealing, improve user satisfaction, and reduce negative affect. In practice, the context of use and the user (or the organization) are often studied together, referring to the wider context. The system solution produced is based on the outcomes of the previous steps and enriched by guidelines on visual design, interaction design, usability, and so on. This step may conclude with a prototype of the system, ranging from a simple paper mock-up to a first executable program version. Finally, the system solution is evaluated against the requirements that were previously identified. Here, usability tests are a commonly applied method, whereby potential users perform a standardized task using the prototype (International Organization for Standardization, 2019). The HCD process should be repeated iteratively until the solution meets the identified requirements. This means to jump back to any prior step in the process to revise or complement solutions as well as research and design activities (Maguire, 2001).

HCD itself is a subject of research. However, in the present work, it is used as a design framework to address the problem of aggressive driving and to determine and structure the corresponding research and design activities.

2.4.2 Initial Research Questions

As suggested by the HCD process, the wider context should be considered in the first place. What constitutes the wider context within the present research is derived from Shinar (1998), who assumes that aggressive driving can be mitigated by either (i) changing the driver's behavior directly or (ii) changing the situational source of frustration. This assumption stresses the need to understand how aggressive driving can be regulated as well as the sources of frustration behind the wheel.

Per definition, frustrating sources block the driver from achieving his goal of moving ahead and are accompanied by an unpleasant emotional experience (Berkowitz, 1989; Dollard et al., 1939). Thus, hereinafter, we are talking about *emotional triggers of aggression*. The need to understand and determine such triggers was already claimed by Shinar (1998) over 20 years ago. Today, two decades later, a lot has changed, including our cars and mobility behavior. All the more, the question arises of what elicits negative emotions in modern driving, leading to the first research question (RQ1): *what are the emotional triggers of aggression in modern driving?*

The therapeutic interventions introduced (*2.3.1 Therapeutic Interventions*) already demonstrated effective ways to change aggressive driving behavior directly. However, these interventions were primarily applied to criminal or hostile drivers and show little potential for technical implementation. Nevertheless, therapeutic knowledge can be an interesting source of inspiration for the present research. Accordingly, effective interventions for "normal" people should be identified, and possibilities for their implementation in the car should be considered, resulting in the second research question (RQ2): *what are the interventions to change aggressive behavior in everyday situations?*

In *chapter III* to *VII*, the initial research questions, as well as follow-up research questions and hypotheses, are empirically studied. RQ1 is examined through a naturalistic driving study (study 1) in which participant drivers reported triggers of emotional experiences while driving. To answer RQ2, interviews with experts concerned with the treatment of aggressive individuals (study 2) were conducted. Afterwards, a series of ideation workshops were run to generate ideas to mitigate aggressive driving (study 3). The workshops revealed inspiring impulses that evolved into a concrete system concept. An online survey (study 4) was conducted to get a first evaluation of the concept. Finally, the concept was prototyped and evaluated in an experimental driving study (study 5) with a focus on the system's perception and effectiveness.

All studies involving human subjects have been reviewed and approved according to the Daimler Ethical Clearing Process, which is supervised by an internal institutional review board.

III. CHAPTER

TRIGGERS OF AGGRESSION ON THE ROAD

3.1 Background

The empirical research described in this chapter is aimed at identifying the emotional triggers of aggression in modern driving to address RQ1 *(What are the emotional triggers of aggression in modern driving?)*. The relevance of this objective is rooted in the assumption that aggressive driving can be changed by preventing, removing, or manipulating these triggers, including external events (e.g., congestion) and objects (e.g., other road user) as well as internal thoughts (e.g., memories) and conditions (e.g., hunger; Shinar, 1998).

When it comes to the subjective measurement of emotional experiences, the only access to this kind of information is through self-reports, either in the form of *forced-choice* or *free* responses. Forced-choices are made based on a preselection of emotional experiences. Here, two major approaches have emerged (Scherer, 2005): categorical and dimensional. The categorical approach confronts the respondent with distinct categories of emotions (e.g., anger, relaxation, surprise) and asks him to choose the one that best characterizes his current state. With the dimensional method, emotional experiences are rated along bipolar axes, such as valence (e.g., positive vs. negative), arousal (e.g., calm vs. excited), or tension (e.g., tense vs. relaxed). The axes are arranged in a two-dimensional space, in which each emotion is represented as a single point (Crispim et al., 2015). When people describe their feelings in their own words, they are not primed or restricted by any predefined choices. Thus, free responses can be seen as the “ground truth” of emotional experiences (Healey, 2011).

No matter how emotions are measured, they are always triggered by a stimulus, ranging from internal thoughts and conditions to external events and objects (Gross, 1998). Most studies that measure drivers’ emotions and their triggers use retrospective methods, e.g., diaries or interviews, that consult participants *after* the drive (Jeon & Walker, 2011; Underwood, Chapman, Wright, & Crundall, 1999). Due to memory biases, participants mainly remember extreme emotions (but forget minor ones) and better recall emotions they experienced at the beginning or the end of the drive (Fredrickson & Kahneman, 1993; Murdock, 1962). A solution to this problem is to ask people in-situ so that their reports are as close to the emotional episode as possible (Laurans, 2011). A relevant study in this regard was conducted by Mesken, Hagenzieker, Rothengatter, and de Waard (2007), who investigated the frequency, determinants, and consequences of emotions behind the wheel. For this, 44 participants completed a 50-minute drive in a test vehicle on a public road. They were accompanied by an experimenter, who asked them every three minutes to verbally report their emotional state using the categories “anger,” “anxiety,” “happiness,” and “no emotion.” In addition, the driving environment was video recorded. On average, anxiety (Ø 2.6 times per drive) was the most reported emotion, followed by anger (Ø 1.5) and happiness (Ø 1.0). Based on the video recordings, the authors determined the agent responsible for each emotion. As a result, anger and happiness were mostly triggered by other road users, while anxiety was mainly caused by situational factors. Unfortunately, the authors do not provide examples or detailed descriptions of the agents. Another limitation of this study is that participants did not drive alone, which could have influenced their emotional experiences and expressions (Niven, Totterdell, & Holman, 2009). Moreover, they were forced to rate their emotions along three categories. These predefined choices do not cover the full range of emotional states that are possible while driving and therefore may have primed the results (Jeon & Walker, 2011; Scherer, 2005).

Beyond these methodological limitations, one should keep in mind that the study of Mesken et al. (2007) was conducted more than ten years ago. Ever since, the conditions on our roads and the standards of our vehicles have changed, which should be reflected in the emotional experiences and triggers occurring in today’s driving. Thus, within this doctoral thesis, a naturalistic driving study was conducted in which participants drove alone in real traffic while tracking their emotional experiences and triggers. In advance, a preliminary study in the form of a retrospective survey was carried out, which is presented first.

3.2 Preliminary Study

The preliminary study was aimed to justify the investigation of RQ1 in an elaborated driving study by quickly demonstrating that there is a significant amount of negative emotional experiences and triggers in modern driving. For this, a survey was carried in which people just arrived at a car park were asked about what they had experienced during their previous drive.

3.2.1 Method

Procedure

In order to semi-standardize the survey, an interview guide was used. Initially, respondents were asked to describe their previous drive, including its purpose, duration and distance, time of congestion, and vehicle driven (Appendix 1.1). Following, they gave a summary assessment of the drive in terms of its emotional valence, i.e., if it was negative, positive, or neutral overall. Finally, they freely reported triggers that elicited negative as well as positive emotional experiences during the drive. No sociodemographic data were collected. The survey lasted around five minutes.

The survey was carried out in December 2017 in two parking lots in the city center of Stuttgart (Germany) on a Monday (7 a.m. to 9.30 a.m.) and a Saturday (10 a.m. to 3 p.m.). The dates and times were chosen so that they represent two different scenarios: Monday morning when people are on their way to work and a weekend day when the focus is on leisure activities. Respondents were approached directly after getting out of their car and interviewed by one of five interviewers (3 female, 2 male). If several people were in the car, only the driver was interviewed.

Sample

In total, 109 respondents were surveyed, 59 on Monday (with 53 on their way to work) and 50 on Saturday (with 39 going shopping). On average, their drive was 50.3 kilometers ($SD = 68.3$) and took 48.46 minutes ($SD = 32.47$). In 35.8 percent of the cases, there was congestion (no congestion: 37.6 %; no answer: 26.6 %) with an average delay of 20.69 minutes ($SD = 14.11$), which corresponds to 36.1 percent of the average driving time ($SD = 16.8$). The most driven vehicle brand was Volkswagen (18.3 %), followed by Audi (16.5 %), and BMW (11.0 %).

Data Preparation and Analysis

In total, 163 emotional triggers were extracted from the interview notes and transcribed into a CSV file, including 76 inherently positive triggers (e.g., nice weather) and 87 inherently negative triggers (e.g., not finding a parking space). The author categorized the negative cases on three levels. On the first level, they were differentiated according to the responsible agent based on Mesken et al. (2007): another road user, the self, an object or event in the driving situation, or a factor not related to the driving situation. On the second level, the type of trigger was specified by inductively formulated categories (e.g., traffic volume or personal issues). On the last level, similar cases were grouped into distinct triggers.

3.2.2 Results

Overall, respondents reported more triggers of negative emotions (87 cases) than positive ones (76). However, according to the summary assessment of the drive, most respondents (36.7 %) rated their previous drive as positive. 34.9 percent experienced the drive as neutral and 28.4 percent as negative.

Focusing on the agents responsible for the triggers associated with negative emotional experiences (Figure 3.2.1), most agents are related to situational factors (66 cases), followed by other road users (16), factors not related to the driving situation (4), and the driver himself (1).

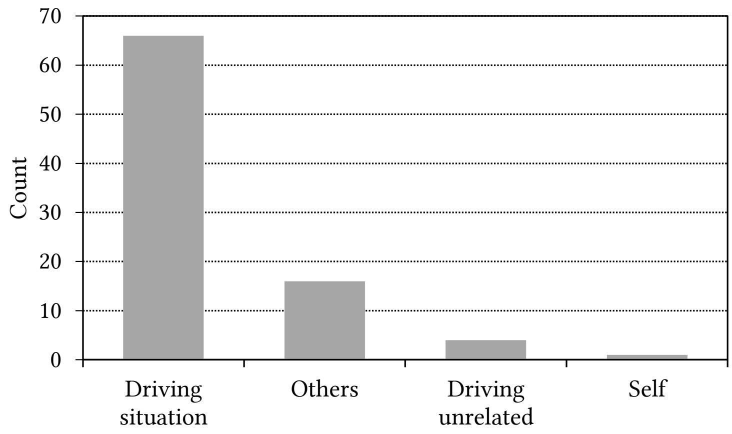


Figure 3.2.1. Agents associated with triggers of aggressive driving (retrospective).

On the second level, the negative triggers can be assigned to eight different types (Figure 3.2.2): traffic volume (31 cases), driving environment (21), interaction with motorized road users (16), parking (9), personal issues (4), traffic lights (3), road conditions (2), and personal driving behavior (1). A description of these types can be found in Appendix 1.2.

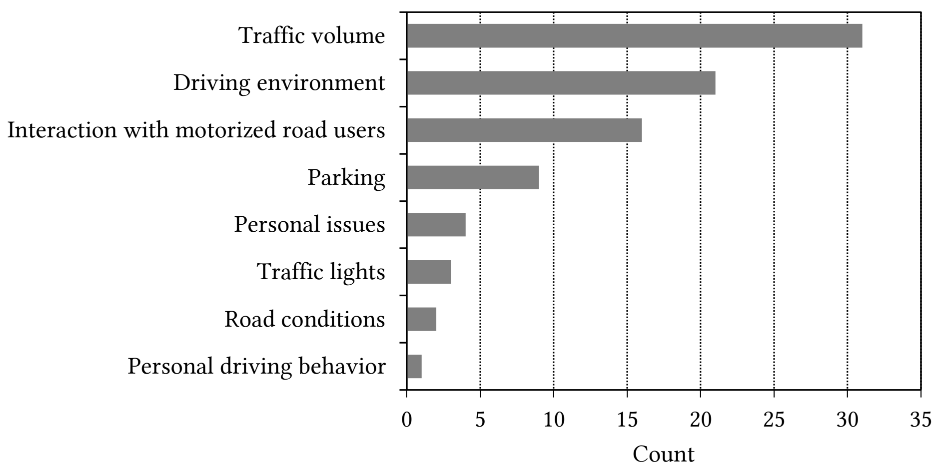


Figure 3.2.2. Types of triggers of aggressive driving (retrospective).

On the bottom level, the 87 cases of negative triggers can be grouped into 23 distinct triggers. The most common one is high traffic or congestion that was reported by 31 respondents. An overview of the triggers as well as their assignment to the different agents and types is given in Table 3.3.1, which includes the results of this survey and the subsequent driving study.

3.2.3 Conclusion and Discussion

Overall, respondents remembered more negative emotional triggers than positive ones. Moreover, more than one quarter assessed the drive as negative overall. Both findings show that there is a considerable amount of negative emotions while driving that might trigger aggression. These outcomes strengthen the motivation to deepen this investigation by conducting a driving study.

3.3 Study 1: Naturalistic Driving Study

In the following study, participants tracked their emotional experiences and triggers while driving in a test vehicle by using a touch screen tablet that was installed in the center console (Figure 3.3.1). The tablet was running an application that captured participants' emotions with both the forced-choice and the free response method.

3.3.1 Method

Emotion Tracking Application

Of the tablet application, two versions were developed (Figure 3.3.2). One version combined the dimensional forced-choice method and the free-response method (dimensional version). The other version used the categorical forced-choice method in combination with the free-response method (categorical version). The two versions were developed to examine the question of which method (i.e., dimensional, categorical, or free responses) is the most valid one to subjectively measure emotions while driving. This question is answered in Dittrich and Zepf (2019), wherein the authors suggest to use driving-specific categories (i.e., stress, anger, annoyance, uncertainty, dislike, relaxation, happiness) in conjunction with the free-response method.

Participants completed two test drives, each with one of the application versions. Independent of the version, they were instructed to track (i) their emotional experiences and (ii) the stimulus that triggered this experience. They were asked to provide this information on their own initiative whenever someone or something, whether linked to the current traffic situation (e.g., another road user) or not (e.g., memories), elicited a feeling in them. However, it was emphasized that safety was of the highest priority and that the application should only be operated if the driving situation allows it.

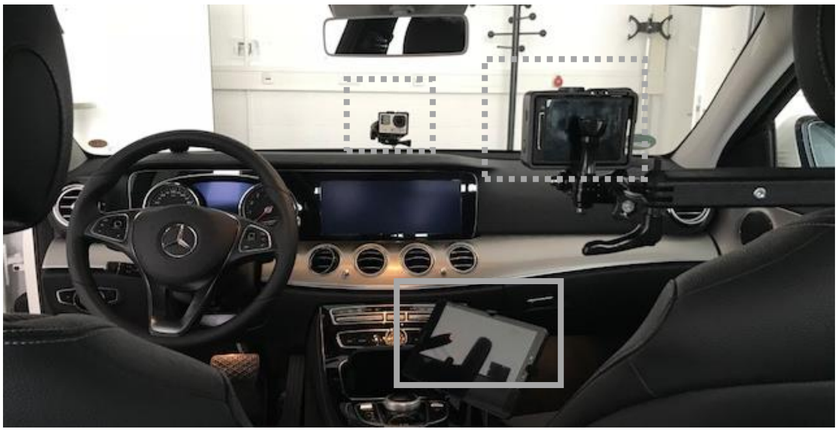


Figure 3.3.1. Position of the tablet running the emotion tracking application (solid line) and the cameras (dotted line).

In the dimensional version, participants indicated their emotional experience by touching a point within a two-dimensional space formed by the bipolar axes “bad-good” (*Ger.* schlecht-gut) and “calm-exited” (*Ger.* ruhig-aufgeregt). The labels were based on the literature and commonly used language (Crispim et al., 2015). Directly after the rating, a voice command was given (“*Voice record started*”) prompting the participants to verbally describe their emotional experience and its trigger in their own words. In addition, a 15-second progress bar was displayed to visualize the remaining recording time. The categorical version consisted of four buttons from which the participants could choose. According to Mesken et al. (2007), the buttons were labeled as “joy” (*Ger.* Freude), “anger” (*Ger.* Ärger), “fear” (*Ger.* Angst), and “other” (*Ger.* anderes). Analogous to the dimensional version, an auditory reminder was given after the rating. The verbal reports were automatically recorded and saved as MP3 files. The numerical values of the dimensional and categorical ratings, including the driver’s position at that time, were logged in a CSV file.

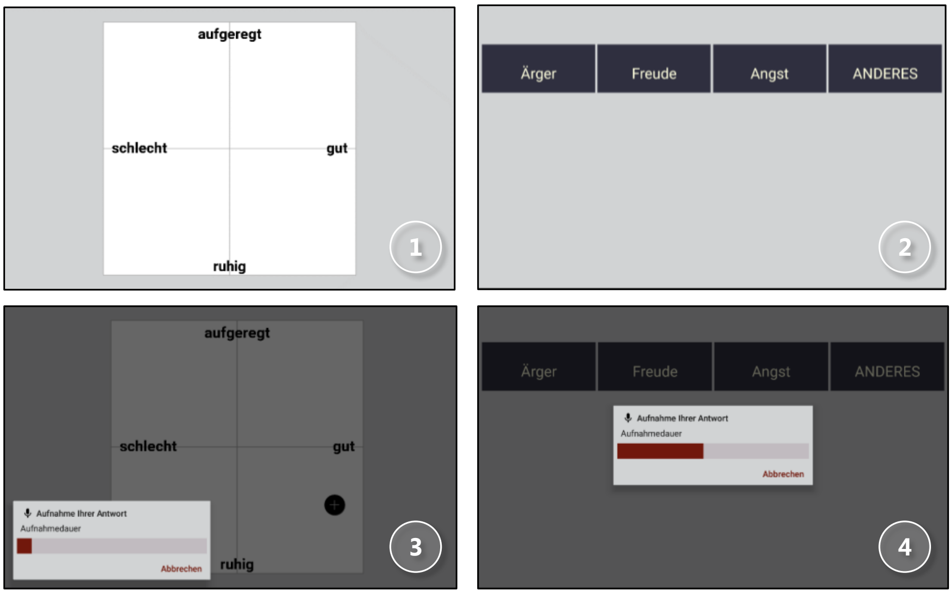


Figure 3.3.2. Dimensional (1, 3) and categorical (2, 4) version of emotion tracking application, including free-response interface with progress bar (3, 4).

To avoid driver distraction, the application meets the following requirements (National Highway Traffic Safety Administration, 2016):

- Only one touch is needed to submit a rating.
- More complex answers are provided verbally.
- No distracting colors or images are used.
- A maximum of 160 characters per frame is used so that the entire content can be perceived at a glance in less than 2 seconds.
- Interaction areas are large enough to hit them from the driver's position.
- Characters are large enough to read them from the driver's position.

Moreover, the application is in line with the German road traffic regulations (Bundesministeriums der Justiz und für Verbraucherschutz, 2016). Accordingly, a driver is allowed to use a mobile device while driving as long as the device is neither picked up nor held in hand, and it is operated exclusively by speech or other interaction methods that require just a brief gaze.

Procedure

The driving study was conducted in summer 2018 between 7 a.m. and 8 p.m. so that different traffic conditions were covered (e.g., rush hour vs. empty streets). The participants took two test drives in real traffic with a Mercedes-Benz E-class sedan that was equipped with the tablet (Samsung Galaxy Tab 6) on which the emotion tracking application was running. In a randomized order, they completed one test drive with the dimensional version of the application and one test drive with the categorical version. In addition, two cameras (Go Pro Hero 4) were installed (Figure 3.3.1); one directed at the driver's face and one directed at the driving environment through the windshield. The test route started and ended at the Mercedes-Benz research laboratory in Böblingen (Germany) and included sections on the highway, along country roads, and in the city (Appendix 1.3). In total, the route was around 14 kilometers long. Participants traveled alone, guided by the on-board navigation system.

Before the first test drive, participants were familiarized with the test route on a map, the test vehicle, and the emotion tracking application. They used each version of the application while standing until they were able to operate it blindfolded. Afterwards, they completed the two test drives one after the other. Between both drives, they stopped at the lab where an experimenter changed the application version. After the second drive, they filled in a questionnaire containing personal background questions (e.g., age, gender, driving experience).

Sample

Participants were recruited via the Mercedes-Benz user study pool (Mercedes-Benz, 2019). The pool includes people interested in customer studies on automotive research and development activities conducted by Mercedes-Benz. Registration is possible for everyone holding a driver's license. Based on the database information, only people whose most used vehicle is a Mercedes-Benz E-class or a comparable car in terms of size, driving performance, and in-car systems were invited. This was intended to create a more realistic driving experience during the study.

In total, 34 participants (20 male, 14 female) took part in the study. Twenty-six participants regularly drove a Mercedes-Benz E-class. Their mean age was 44.6 years (SD = 13.8, min: 21, max: 67) and they drove an average of 25,559 kilometers (SD = 13,800) by car in the last twelve months. In Germany, the average mileage per year ranges between 10,000 and 15,000 kilometers (Statistisches Bundesamt, 2020b). Participants received an expense allowance of 80 Euro. None of them worked at the Daimler Group.

Data Preparation and Analysis

The emotional triggers were described in the audio recordings. In total, 613 recordings were saved, including some incorrect records (e.g., noisy records, missing description of triggers). From the records, both positive and negative triggers were transcribed, resulting in 566 excerpts. These excerpts were merged into the CSV file that contained the dimensional and categorical ratings so that it was possible to determine whether the trigger caused a negative or a positive emotional experience. In 32 cases, no valence indication was possible because the participants opted for the category “other emotion” or gave a dimensional rating without providing a clear verbal description of their emotion. Moreover, 27 responses were excluded because they were contradictory, i.e., they were linked to a negative (or positive) emotion rating but described an inherently positive (or negative) trigger. Consequently, 261 valid cases of triggers linked to a negative emotion and 246 valid cases of triggers linked to a positive emotion were obtained. These were categorized by the author and a student of psychology fulfilling an internship at the Mercedes-Benz Innovation Studio. The coders used the classification scheme of the preliminary study and classified the triggers according to (i) their responsible agent, (ii) their type, and (iii) their similarity to other triggers.

3.3.2 Results

Participants tracked 261 triggers of negative emotional experiences and 246 positive ones. In consideration of the responsible agent (Figure 3.3.3), most of the negative triggers were associated with factors of the driving situation (161 cases; e.g., very long red traffic light), followed by triggers for which other road users are responsible (70; e.g., a truck or another slow vehicle ahead), triggers for which the driver himself is responsible (23; e.g., the feeling of disorientation), and triggers not related to the driving situation (7; e.g., bad music or news on the radio). Both in the car park survey and the driving study, most of the triggers are associated with the driving situation.

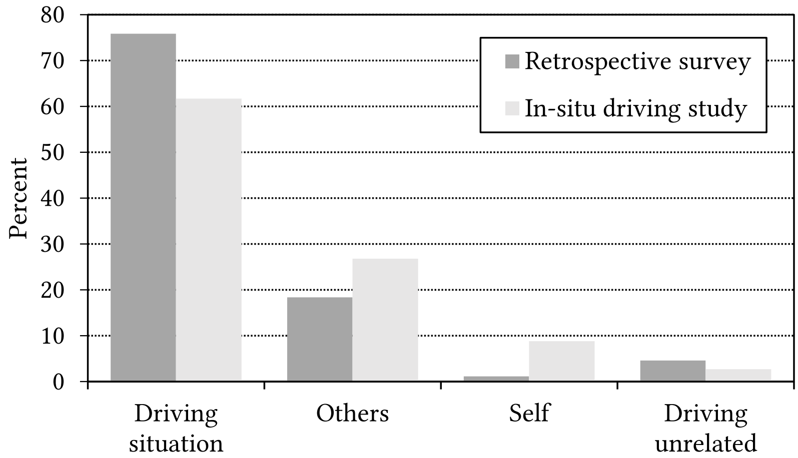


Figure 3.3.3. Agents associated with triggers of aggressive driving (retrospective and in-situ).

The 261 negative triggers can be grouped into 14 different types (Figure 3.3.4). From these 14 categories, seven are already known from the retrospective survey, including interactions with motorized road users (61 cases identified in the driving study), traffic lights (39), road conditions (17), traffic volume (11), driving environment (10), personal issues (2), and the driver's own behavior (1). The seven new types that were identified in the driving study are vehicle (37), navigation (32), driving speed (9), arrival (6), interaction with non-motorized road users (9), orientation (22), and entertainment (5). In contrast to the retrospective survey, no parking-related triggers occurred in the driving study. A description of each type is given in Appendix 1.2. In order to determine the most common type across both studies, the results of the retrospective survey and the driving study were combined by calculating the relative frequencies of each type. As depicted in Figure 3.3.4, unpleasant interactions with other motorized road users were the main source of negative emotions. Considered across both investigations, 22.9 percent of all triggers were assigned to this type.

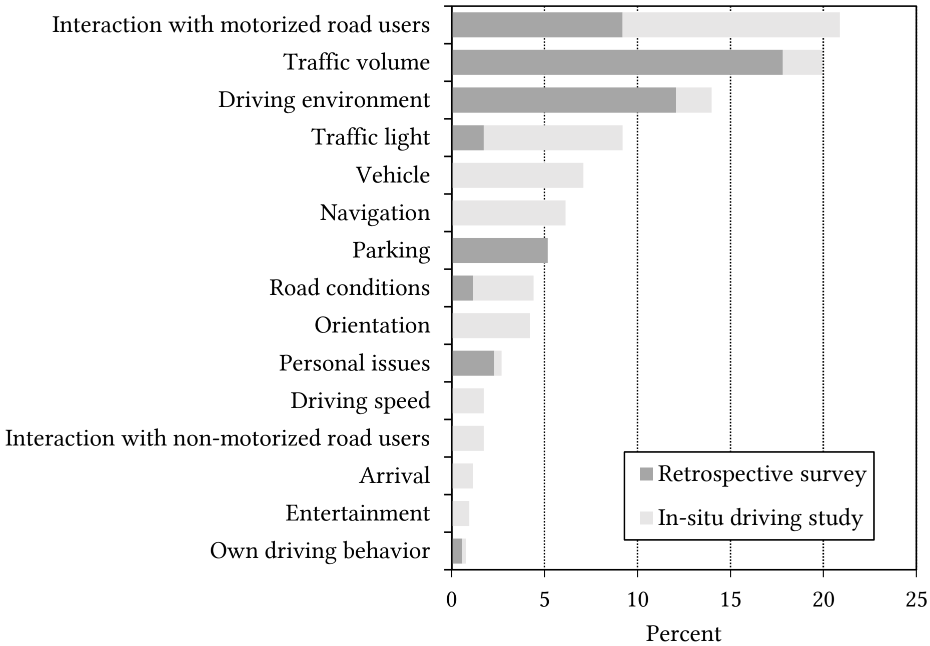


Figure 3.3.4. Types of triggers of aggressive driving (retrospective and in-situ).

The 261 cases of negative triggers can be grouped into 63 distinct triggers. Participants most frequently complained about incorrect, delayed, or ambiguous navigation commands (25 cases). Also, red lights (20), the poor usability or user experience of the in-car systems (20), or the feeling of “getting lost” (18) often evoked negative emotions. The distinct triggers identified in the retrospective survey and the driving study are summarized in Table 3.3.1, including a total of 75 distinct triggers.

A heat map based on the geo information linked to the triggers, shows their distribution along the test route (Figure 3.3.5). The heat map was created with the help of Google Fusion Tables. As this figure shows, triggers occur particularly at intersections. Here, road users interact with each other, traffic lights are positioned, and navigation commands are given. In contrast, straight road sections trigger fewer negative emotions and therefore have less aggressive potential.

Figure 3.3.5. Heat map of triggers of aggressive driving (larger color areas represent a higher number of triggers)

Table 3.3.1. Distinct triggers of aggressive driving identified in the preliminary study (retro) and the naturalistic driving study (in-situ).

Trigger	**Count**	
	In-situ	**Retro**
Driving situation	161	66
Traffic lights	39	3
(Frequent) red light(s)	20	3
Just missing a green light	10	-
Very long red light	7	-
Red traffic light at an empty street	2	-
Vehicle	37	-
Bad usability / user experience of in-car systems	20	-
Unknown warning	7	-
High fuel consumption	2	-
Driving an unknown car	2	-
Limited view due to vehicle pillars	2	-
Constricting seat belt	1	-
Bad driving comfort and performance	3	-

Continuation of Table 3.3.1.

Trigger	**Count**	
	In-situ	**Retro**
Navigation	32	-
Wrong / delayed / ambiguous navigation command	25	-
Unexpected navigation route	7	-
Road conditions	17	2
Limited visibility of traffic signs / road sections	5	-
Complex intersection	3	-
Speed bump	2	-
New road	2	-
Challenging road section	3	-
Missing / ambiguous traffic signs	2	-
Slippery / snow-covered road	-	2
Traffic volume	11	31
High traffic / congestion	6	31
Anticipation of congestion	5	-
Driving environment	10	21
Police car / ambulance / traffic accident	3	4
Smelly vehicle	2	-
Heat	2	-
Roadworks	1	6
Speed camera	1	3
Dead animal on the roadside	1	-
Early morning	-	6
Bad weather	-	3
Driving speed	9	-
Speed limit	5	-
Waiting at an intersection	4	-
Arrival	6	-
Arriving later than expected	6	-
Parking	-	9
Small parking space	-	4
Not finding / looking for a parking space	-	2
Favorite parking space was occupied	-	1
High prices for parking lots	-	1
Small car on big parking space	-	1
Others	70	16
Interaction with motorized road users	61	16
Slow vehicle / truck ahead	16	5
Merging in the lane directly before the ego vehicle	6	-
Not using indicators	6	2
Driving in the blind spot	4	-
Blocking the left lane	3	3
Tailgating	3	2

Continuation of Table 3.3.1.

Trigger	Count	
	In-situ	Retro
Cutting the one's own lane	2	2
Missing a green light due to a slow vehicle ahead	2	-
Throwing garbage on the street	2	-
Not driving off at a green traffic light	2	-
Overtaking on the right	2	1
Honking	2	-
Jumping a red light	2	-
Blocking the street in front of an intersection	2	-
Driving school ahead	1	-
Exceeding the speed limit	1	-
Changing lanes at an intersection	1	-
Driving in snaky lines	1	-
Driving very close beside the ego car	1	-
Jumping between lanes	1	-
Not allowing the ego car to merge in the lane	1	-
Insulting gesture	-	1
Interaction with non-motorized road users	9	-
Near-collision with a cyclist	3	-
Pedestrian crossing the street shortly before one's own car	3	-
Pedestrian walking very close to the street	1	-
Cyclist pushing himself at a red light	1	-
Pedestrian crossing the street at a red light	1	-
Self	23	1
Orientation	22	-
Getting lost	18	-
Disorientation	4	-
Personal driving behavior	1	-
Exceeding the speed limit	1	-
Driving to close to another vehicle	-	1
Not related to the driving situation	7	4
Entertainment	5	-
Annoying advertisement	4	-
Bad music / news	1	-
Personal issues	2	4
Time pressure	-	2
Poor health	-	2
Family and friends	1	-
Forgetting something	1	-

3.3.3 Conclusion and Discussion

Both the naturalistic driving study ($N = 34$) and the retrospective survey ($N = 109$) revealed that there is a significant number of negative emotional experiences and triggers in modern driving. Answering RQ1 *(What are emotional the triggers of aggression in modern driving?)*, 75 distinct triggers from 15 categories were identified in both studies: (i) traffic lights, (ii) vehicle, (iii) navigation, (iv) road conditions, (v) traffic volume, (vi) driving environment, (vii) driving speed, (viii) arrival, (ix) parking, (x) interaction with motorized road users, (xi) interaction with non-motorized road users, (xii) orientation, (xiii) personal driving behavior, (xiv) entertainment, and (xv) personal issues. Especially interactions with motorized road users caused negative emotions in the subjects. This category refers to illegal and illegitimate actions of other drivers that are directed at oneself, others, or the environment, such as tailgating, slow driving, or throwing trash on the street. Aside from very common triggers, the studies also revealed less obvious examples such as smelly vehicles, other road users ignoring a red light, or negative thoughts.

From these findings, three assumptions for future investigations can be derived. First, triggers associated with other road users demonstrate a vicious circle: illegal and illegitimate actions of other road users might trigger negative emotions and aggressive tendencies in a driver. If he enacts this aggression, the driver himself is a negative trigger for others. In other words, aggressors are victims, and victims are aggressors (Calaguas, 2012). Second, although people experience driving as something positive overall, they report more negative emotional triggers than positive ones. This suggests that the number of negative triggers experienced while driving has only a small effect on the overall emotional assessment of the drive. Third, in Mesken et al. (2007) fear was the most frequently reported emotion. In the present driving study, this emotion barely occurred, as a post-hoc analysis has shown (Dittrich & Zepf, 2019). This shift could be attributed to the improved safety, comfort, and entertainment standards of modern cars, making driving a more positive emotional experience in general (Gkouskos, Pettersson, Karlsson, & Chen, 2015)

The major methodological limitation of the driving study is that, despite all efforts, the driving experiences created within the study are not truly realistic, which threatens the external validity of the results. It would be desirable to replicate this study with participants driving their own cars, in a private context, and over a longer period of time so that situations can be observed that do not occur under experimental settings (e.g., on the way home from work, on vacation, or when children are on board).

Each of the identified triggers of negative emotional experiences is a potential source of aggression on the road and part of the wider context of the future system. In the further course of this work, these triggers are used to inspire the development of solutions to mitigate aggressive driving. Before, another aspect of the wider context is examined in the following: the driver. More precise, the interest is focused on interventions to mitigate a driver's aggression directly.

IV. CHAPTER

INTERVENTIONS AGAINST HUMAN AGGRESSION

4.1 Background

Besides mitigating aggressive driving by preventing, manipulating, or removing triggers of aggression, such behavior can also be changed directly (Shinar, 1998), which is the concern of RQ2 that focuses on intervention against human aggression (*What are the interventions to change aggressive behavior in everyday situations?).* There are several practical domains with a long tradition in the treatment of human aggression, such as psychotherapy, special education, or forensic psychology. Involving stakeholders from these domains, the aim of the following investigation is to determine effective strategies that people may use to mitigate aggression in everyday situations and that have the potential to be translated into technical solutions for the automotive domain.

Much of the practical knowledge about how to regulate aggression comes from emotion research. In principle, each emotion is accompanied by physiological, attentional, behavioral, and expressive responses as well as the subjective experience of the emotion. Whenever an individual tries to modify at least one of these emotional components in terms of occurrence, form, duration, or intensity, this is called emotion regulation. The emotion regulation process can be directed at both positive and negative emotions by either increasing or decreasing them, and it can be managed by the self or an external regulator, including objects, situational factors, and other people (Gross, 1998). The most common framework of emotion regulation is the *process model of emotion regulation* (Gross & Thompson, 2007). The model distinguishes five regulative sub-processes that are directed at different phases of the emotion-generative process, including the situation in which the emotional trigger occurs (situation selection and modification), the individual's focus of attention in this situation (attentional deployment), the individual's appraisal of this situation (cognitive change), and the individual's emotional response (response modulation; Figure 4.1.1). Situation selection, for example, refers to avoiding (or approaching) situations that are expected to elicit undesirable (or desirable) emotions. Cognitive change is every attempt to change one's appraisal of the emotion-arousing stimulus (Gross & Thompson, 2007).

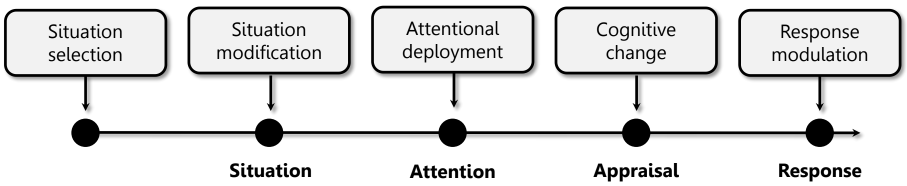


Figure 4.1.1. Process model of emotion regulation according to Gross and Thompson (2007).

As noted, different practical domains are concerned with the treatment of aggressive people and the issue of emotion regulation. In psychotherapy, the clinical application of emotion regulation techniques and the improvement of clients' emotion regulation skills are part of the daily business. Deficits in the capability to regulate emotions contribute to the development of mental disorders, such as depression, phobias, or alexithymia. In the case of people with mental disorders, poor emotion regulation skills, moreover, can promote aggressive behavior patterns (Rottenberg & Gross, 2007). Also, for the rehabilitation of offenders (e.g., traffic, violent, or sexual offenders) and other forensic clients (e.g., stalkers or persons running amok), the issue of emotion regulation is of practical relevance as negative emotions increase the likelihood of offenses (Day, 2009; Harvey & Smedley, 2012). Aggression and negative emotions are also common in working environments. Studies have shown that anger correlates not only with workplace aggression and violence (e.g., leaving the work area when the target enters or threats of physical attacks) but also with other negative reactions, such as increased blood pressure, stress, or reduced cooperation and productivity (Miron-Spektor & Rafaeli, 2009; Neuman & Baron, 1998). When conflicts with or between colleagues, employees, or executives escalate, de-escalation or anti-aggression trainers are deployed. Their work focuses on promoting interpersonal communication and empathy (Rew & Ferns, 2014). In sports—especially in martial arts—being aggressive is considered an optimal affective state due to the mobilizing function of aggression. Emotion regulation techniques can help to maintain this "optimal state", which is dynamic in nature (Ruiz & Hanin, 2004).

Inspired by these domains, the following sections present the results of expert interviews that were conducted to determine effective interventions against human aggression. The expert approach is supposed to show its benefits in two ways. First, since experts are "a carrier of deep knowledge of the research object" (Libakova & Sertakova, 2015, p. 117), their opinion is seen as fact, and insights derived from consulting them have a high external validity. Second, according to the theory of creativity, design processes should draw on the potential of cross-domain knowledge to foster creativity (Scotney, Weissmeyer, & Gabora, 2014). By interviewing experts from outside the context of driving, the expert approach also might increase the diversity of the results.

4.2 Study 2: Expert Interviews

4.2.1 Method

Sample

In total, 15 German experts (9 female, 6 male) that were concerned with human aggression professionally were interviewed (Appendix 2.1). On average, they had 14 years of professional experience in their respective field. Five experts worked in the (psycho-)therapeutic sector (P2, P8, P11, P13, P15). Their clients included individuals with mental disorders, criminals in open and closed prisons, violent children or adolescents, and traffic offenders. Two experts had a professional background in traffic research (T3, T14), one in martial arts (S1), three in probationary services, offender assistance, and forensic psychology with a focus on extreme cases (e.g., violent and sexual offenders, people running amok, or stalkers; F4, F7, F12), and three in de-escalation and personal coaching for local government, healthcare institutions, or schools (D5, D6, D9). One expert (D10) was a physicist participating in a Mars simulation. The simulation was aimed at figuring out how an astronaut crew deals with interpersonal conflicts in a small space.

The experts were recruited by a non-random technique. Initially, interesting persons were searched for online. For this, the keywords “aggression” and “emotion regulation” were combined with terms related to relevant domains, such as “de-escalation” or “psychotherapy.” The search results were screened for websites of institutions and self-employed practitioners in German-speaking countries. Once a potential candidate was identified, he was contacted by phone. If the person was interested, an email was sent for further communication and the arrangement of the interview. All of the first contacts were generally open to the inquiry, and almost everyone agreed to an interview. Some of the first contacts, who did not want to participate, forwarded the request to colleagues or relatives.

Procedure

The interviews were held by the author and conducted either by telephone or at the experts’ place of work. The sessions lasted between 45 and 90 minutes and were either audio-recorded (if participants consented) or protocoled by taking notes. The interviews were semi-structured, supported by a topic guide including key and probing questions on (i) the experts’ understanding of aggression (i.e., types of aggression, triggers of aggression, emergence of aggression, relation between frustration and aggression) and (ii) their working practices with a focus on the regulation of aggression (i.e., interventions applied in face-to-face sessions with the client, interventions suggested for everyday situations, interventions in the context of driving, relationship with clients; Appendix 2.2). Additionally, probing techniques were used. First, the experts were asked to describe a typical aggressive client and the interventions they have applied in such a case. Second, they were asked to imagine sitting in a car next to an aggressive driver and suggest appropriate interventions to calm him down.

Data Preparation and Analysis

The interviews addressed the issue of human aggression and its regulation holistically. The most interesting insights with respect to this thesis are the practically used intervention against aggression. Thus, the first step in data preparation involved transcribing expert statements from recordings and notes that include a concrete example of how to change aggressive behavior—whether inside or outside the context of driving. For this, the qualitative data analysis software MAXQDA was used. In total, 204 intervention examples were extracted.

Second, the examples were summarized and structured by building an affinity diagram (Figure 4.2.1), which is an interactive way to organize field data into a consensual hierarchy (Holtzblatt & Beyer, 1993).

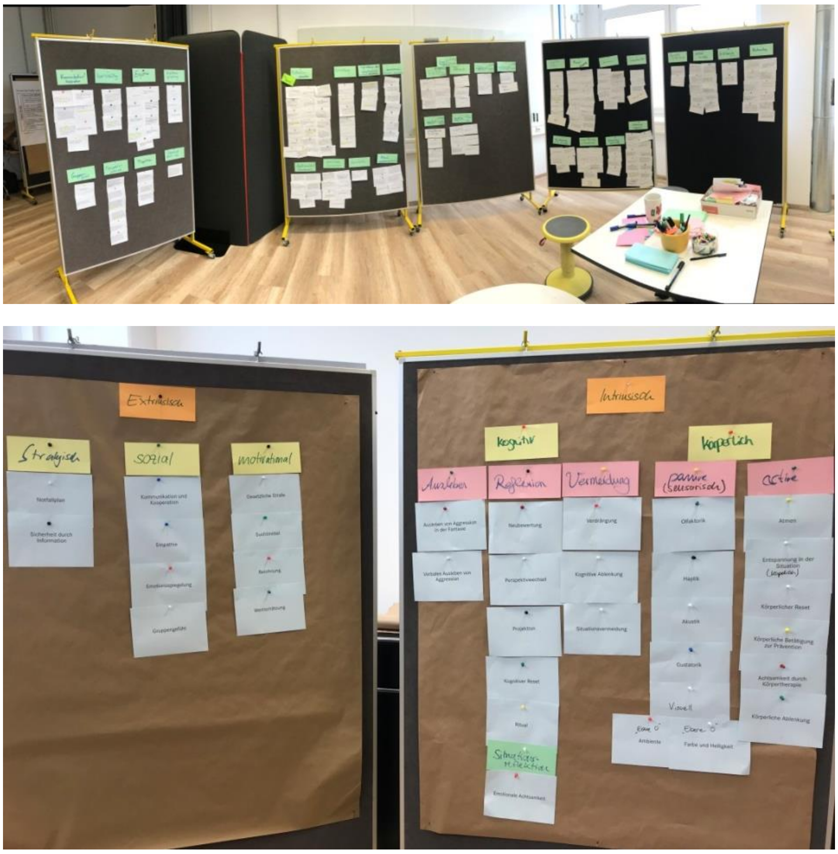


Figure 4.2.1. Groups of anti-aggression (top) and their classification (bottom) obtained from the affinity diagram.

For this, the 204 transcripts were printed on paper notes and clustered on a pinboard by six employees working at the Mercedes-Benz Innovation Studio (3 permanent employees, 3 students completing an internship). At the beginning of the session, they were briefed about the design goal of this thesis, i.e., the development of a technology solution to mitigate aggressive driving. Then, in the first step, ten randomly chosen notes were given to each participant (in total 60 notes), which they grouped and labeled into clusters on their own. They formed an initial cluster and worked through the remaining notes by checking each one, whether it could be assigned to the existing cluster or not. If not, a new cluster was formed. This procedure was repeated until the ten examples were clustered. In the second step, participants clustered the remaining 144 notes in collaboration. This time, they checked each note against the existing clusters of all participants. Again, if no matching cluster existed, a new one was formed. Moreover, participants were allowed to reassign examples, rename clusters, and structure clusters hierarchically by forming higher-level categories.

The affinity diagram session took around four hours and revealed 34 distinct anti-aggression interventions that were categorized on three levels. The classification scheme obtained by the participants was digitalized as depicted in Figure 4.2.2 and provided the basis for the following presentation of results.

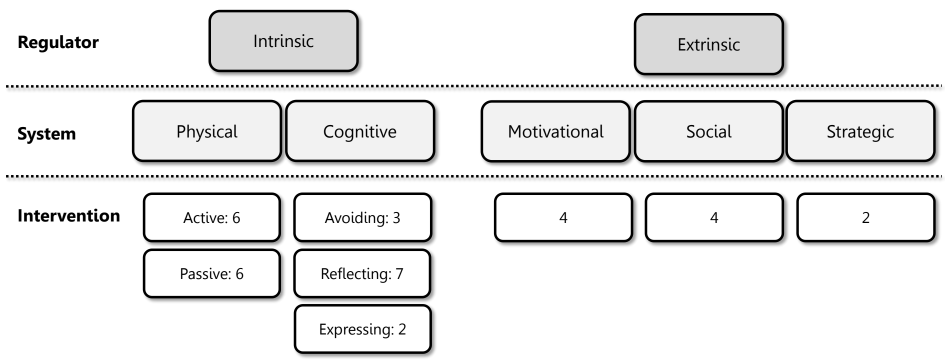


Figure 4.2.2. Classification of the anti-aggression interventions (numbers indicate the number of distinct interventions per category).

4.2.2 Results

Within the affinity diagram, 34 distinct interventions to mitigate aggressive behavior are classified on three levels. The distinct interventions represent the bottom level of this classification scheme, with each intervention grouping similar intervention examples together. They are presented in Table 4.2.1, including a short description and illustrative examples of each intervention. On the top level, the classification distinguishes between *intrinsic* interventions (24 distinct interventions) and *extrinsic* interventions (10). Intrinsic interventions are initiated by the self, while extrinsic ones are triggered by an external stimulus. On the second level, the interventions are specified according to the human system at which they have their primary impact, i.e., *physical* (12), *cognitive* (12), *motivational* (4), *social* (4), and *strategic* (2). Physical and cognitive interventions are intrinsic by nature, while the remaining types are inherently extrinsic. The five second-level categories of interventions are described in detail below.

- **Physical interventions** involve the body and can be further characterized as *active* (6) or *passive* (6). Active physical interventions refer to the performance of physical activities and passive physical interventions refer to the perception of sensory input. An intervention example of the physical-active category is *breathing*, such as the short shout uttered when executing an attack in martial arts, named "Kiai" (S1). Here, the entire body is tensed for a short time, which focuses the physical energy and mental attention on the upcoming action. An exemplary intervention of the physical-passive category is *gustatory stimuli* (e.g., chili peppers or sour candies) that override the experience of aggression (F12).
- **Cognitive interventions** require controlled cognitive processes. They support the individual in *avoiding* triggers of aggression (3), *reflecting* on the situation in which the feeling of aggression arises (7), or *expressing* an aggressive inclination in a non-harmful way. *Cognitive distraction*, i.e., to think about something different, is a common example of the avoidance category. An exemplary expressive intervention is the *verbal expression of aggression* by screaming, swearing, or talking to another person. To talk about their aggressive inclinations and experiences, astronauts have an unbiased contact person on the ground to talk to when there are conflicts with other crew members (D10). A *ritual* is an example of

a reflective intervention. One of the experts told of a client who lost his driver's license and, as a result, had to use public transport (F7). After the return of his driver's license, he fixed his last train ticket to the dashboard of his car. When aggression was boiling up again while driving, he would look at the ticket to remember how much he dislikes public transport.

- **Motivational interventions** are directed at the reward center of the aggressor—his motivation—and refer to extrinsic motivators that can be material (e.g., *addictive substances*) or social (e.g., *appreciation*) in nature.
- **Social interventions** are embedded in social interactions between the aggressor and the target of aggression or the aggressor and trigger of aggression. Given the example of *verbal and non-verbal communication* on the road, the only available information about other drivers is, "How quickly does another vehicle approach? At what distance does another vehicle enter my personal space? How big is the other vehicle?" (P13). If the interplay between driving speed, following distance, and status of the car is adequate, this can have a de-escalating effect.
- **Strategic interventions**—in contrast to cognitive interventions—activate automatic cognition by providing the aggressor with information that is easy to process. In psychotherapy, for example, *emergency plans* for outbursts of rage answer questions such as "Where can I go, who can I call?" (F7). The aim is to internalize this plan so that it is automatically activated in critical situations and leads the aggressor to the right way.

As noted, the 34 distinct interventions represent the bottom level of the classification scheme. Besides these interventions, the experts generally emphasize the relationship with the client as a mediating factor for the effective implementation of the interventions. A good relationship is characterized by demonstrating empathy, appreciation, and interest toward the aggressor (8 experts) as well as by protecting the aggressor's self-determination (3).

Table 4.2.1. Distinct anti-aggression interventions.

Intervention	**Description**
Intrinsic – physical – active	
Breathing	"Aggression leads to gasping respiration, so that the frontal brain, which is responsible for clear thinking, is no longer adequately supplied with oxygen. To counteract this, one needs to consciously take a deep breath" (F12). Here, "three to four breaths are already enough to calm down" (F4). An imaginative method to guide breathing is the "anger meter" (P2), whereby one has to envision a speedometer and to breathe down in analogy to this. Another technique is the "Kiai" (S1), a battle cry known from martial arts.
Physical activity	A low adrenalin level and optimal hormone balance prevent aggression and can be achieved through daily physical activity and sport.
Physical distraction	Doing something not related to the aggressive experience, such as dipping into work or walking backward.
Physical reset	Physically leaving the situation; in the driving context, for example, by getting out of the car, handing the car over to another person, or changing lanes to let a tailgater pass.
Relaxation	Recommended relaxing exercises include kneading a stress ball, progressive muscle / Jacobsen relaxation, autogenic training, or contracting hands and arms in slow motion.
Somatic experience	Somatic experiencing puts the focus on what is felt in the body while being aggressive (e.g., cramped face). If an inverse behavior is shown (e.g., smiling), the emotional state is adjusted toward this behavior.
Intrinsic – physical – passive	
Acoustic stimuli	Acoustic stimulation can be reached through music. However, what kind of music is appropriate in the given situation depends on individual preferences.
Ambience	The environment should be designed to be minimalist and clean (to avoid arousal) or warm and domestic (to create a feeling of safety).
Color and brightness	Calming colors are light versions of pink, blue, or green. Red can have a calming effect as its association with anger serves as biofeedback.
Gustatory stimuli	Gustatory stimuli can decrease aggressive behavior, if the intensity of the gustatory experience overrides the emotional experience, such as chili peppers or sour candies.
Haptic stimuli	Haptic activities include, for example, a foot massage, painting and working with clay, taking a cold shower, or having a cold drink.
Olfactory stimuli	Calming scents are ammoniac, orange, and lemongrass.

Continuation of Table 4.2.1.

Intervention	Description
Intrinsic – cognitive – reflecting	
Change of perspective	Aimed at promoting forgivingness, the aggressor takes on the perspective of the target of aggression. For example, offenders are confronted with videos of their victims, describing their view of things, and take on their perspective through role-playing.
Cognitive reset	Stop thinking about the situation by literally "making a point" (P2).
Emotional mindfulness	Emotional mindfulness, i.e., consciously dealing with your feelings, can be achieved by explicitly naming or ranking one's emotions. Creative methods include the painting of emotions or the creation of associations via stories, pictures, or colors.
Projection	Similar to a scapegoat, the aggressive behavior is directed at a person or object that has nothing to do with the current situation.
Reevaluation	The reevaluation of the situation can be promoted by emphasizing the ineffectiveness or negative consequences of a behavior: "It makes no difference if you drive at 160 km/h or 100 km/h from Munich to Hamburg; you will arrive at the same time" (T3). Another technique is the "time catapult" (P2), where you ask yourself if the situation is still relevant in the future. Besides, reevaluation can be triggered by positive associations: "Whenever I see the road sign [...], I've made it half of the way home. Then I'm happy" (P2).
Ritual	Rituals, such as the bow in martial arts or the handshake at the greeting, contain the promise not to harm each other. They function as a prime that prevents aggressive behavior.
Situation reflection	In general, situation reflection can be triggered by warnings that direct the attention to the stimulus that elicited the aggressive behavior or by messages that increase self-awareness (e.g., "Take care, you're getting aggressive," P2) and responsibility (e.g., "I got into this situation, because I'm traveling by car. I could also go by train or bike", D5).
Intrinsic – cognitive – expressing	
Expression of aggression in fantasy	When expressing aggression in fantasy, one's ideas should become increasingly abstract: "initially, instead of hitting him, I imagine hitting him. Then, I imagine I hit somebody or something else. Then, I imagine I'm just doing something else" (P15).
Verbal aggression	Aggression can be expressed verbally by screaming and swearing or talking to another person.

Continuation of Table 4.2.1.

Intervention	Description
Intrinsic – cognitive – avoiding	
Cognitive distraction	Cognitive distraction means to think about something else, for example, through counting backwards, watching television, observing the environment, thinking about something humorous or positive memories.
Situation avoidance	An individual's attempt to avoid a situation needs to be triggered. To provide an example of such a trigger, one of the experts described a client who was forced to use public transit when his driver's license was revoked After he received his driver's license again, he put his last train ticket on the dashboard of his car. When he became aggressive, he looked at the ticket to remind himself what he hates: public transport (F7).
Repression	To repress aggression, an expert suggested to "mentally create a tray, add the anger, and bring it out later to deal with it" (D10).
Extrinsic – social	
Affect mirroring	Affect mirroring means that another person expresses the same emotion as the aggressor to convey commitment.
(Non-)verbal communication	Good communication depends, among other things, on cooperation and objectivity. In the driving context, there are three non-verbal channels: approaching speed, approaching distance, and car size (P13).
Empathy	Empathy involves understanding and vicariously sharing the feelings of the aggressor, which can be reached by listening to the aggressor's problems and showing attention through touch and eye contact. The more people know about each other, the more empathy increases, for example, knowing about the other's emotional state, demographics, or driving motive.
Team spirit	Above all, activities known from experiential education strengthen team spirit and group feeling.
Extrinsic – strategic	
Emergency plan	Emergency plans facilitate decision-making in the case of aggressive outbursts by providing concrete instructions on what to do (e.g., "Where can I go? Who can I call?", F7).
Security through information	Uncertainty promotes aggressive behavior. To avoid uncertainty, the individual needs information that creates a feeling of security. For example, drivers stuck in a traffic jam should be provided with information on the reasons and the duration of the delay.

Continuation of Table 4.2.1.

Intervention	Description
Extrinsic – motivational	
Addictive substances	Common examples are cigarettes and alcohol.
Appreciation	Appreciative words of others function as a social reward, which reinforces prosocial behavior.
Punishment	Punishing interventions are educational or legal in nature. In the driving context, the most significant penalty is the withdrawal of the driver's license.
Reward	Rewards mainly refer to performance-related reinforcement, such as credit points or good grades.

4.2.3 Conclusion and Discussion

In order to answer RQ2 (*What are the interventions to change aggressive behavior in everyday situations?*), 15 experts dealing with human aggression professionally, were interviewed. The expert sample mainly consisted of professionals from the (psycho-)therapeutic domain but also included other practitioners concerned with the treatment of aggressive individuals, such as an astronaut or a martial artist. The interview material was classified by building an affinity diagram. This method revealed 34 distinct interventions to change aggressive behavior inside and outside the car. The classification scheme obtained structures these interventions on three levels. On the top level, a distinction is made according to the type of regulator that initiates the regulation process, which can be the self (intrinsic) or an external stimulus (extrinsic). The subordinate level specifies the interventions based on the human system they are directed at (physical, cognitive, motivational, social, and strategic). The distinct interventions themselves constitute the bottom level of the classification scheme. This comprehensive overview of anti-aggression interventions stands out due to its diverse and, in part, extraordinary examples, such as drinking a cup of cold water or eating extremely sour candies.

The substantive and methodological discussion is about the external validity of the identified interventions (Libakova & Sertakova, 2015) and their translation into technical solutions for the automotive domain. Considering the external validity, it has to be emphasized that each intervention has to be checked on an individual level and cannot be generalized per se. This becomes clear, for example, by considering the use of music as an intervention to regulate aggression. While some drivers need calm music for this purpose, others prefer aggressive music (FakhrHosseini & Jeon, 2016). Addressing the potential for technical implementation of the interventions, the restricting factors are the risk of driver distraction and the limited freedom of movement in the car (Horberry, Anderson, Regan, Triggs, & Brown, 2006). Given these factors, the implementation of the intervention must be done in such a way (i) that the system task does not interfere with the primary driving task and (ii) that the system task only requires as much physical movement as the automotive space allows.

Together with the emotional triggers of aggression identified in *chapter III*, the anti-aggression interventions help to understand the wider context of the future system and provide the empirical foundation for the next step of the HCD process, aimed at generating ideas of persuasive solutions to mitigate aggressive driving.

V. CHAPTER

IDEAS TO MITIGATE AGGRESSIVE DRIVING

5.1 Background

After gaining an understanding of the wider context of the future system in *chapter II* (triggers of aggression) and *chapter III* (interventions to regulate human aggression), this chapter faces the third stage of the HCD process that is aimed at the ideation of Persuasive Technology solutions to mitigate aggressive driving (Maguire, 2001). More precisely, the goal is to generate *innovative* ideas that stand out from the state of the art.

In the literature, the term "innovation" is a multidisciplinary construct with various definitions (Baregheh, Rowley, & Sambrook, 2009; Wijngaarden, Hitters, & Bhansing, 2019). Among these definitions, the understanding of Joseph Schumpeter, who was the first emphasizing the importance of a product's innovativeness for its economic success, gained considerable attention. According to Schumpeter (1947), innovation is basically "the doing of new things or the doing of things that are already done, in a new way" (p. 149), including the development of new products and services, the adaption of existing solutions, process innovations, or organizational changes. Against this background, it is important to differentiate between an idea and an innovation, claiming that not every idea is innovative per se. The difference lies in the economic success and the individual and social changes associated with the idea (O'Sullivan & Dooley, 2008). An idea's innovative potential is reflected, for example, in its patentability, degree of novelty, design attractiveness, and business feasibility (Justel, Vidal, Arriaga, Franco, & Val-Jauregi, 2007).

It is commonplace that the best ideas pop-up when you least expect them to: in the supermarket, while walking the dog, or in the shower (Ovington, Saliba, Moran, Goldring, & MacDonald, 2018). However, all organizations have to produce innovations on-demand to be competitive (Brem, 2019; O'Sullivan & Dooley, 2008). Thus, both science and practice have begun to develop methods and tools to enhance ideation. In business contexts, ideation workshops are a common way to involve employees and external stakeholders (e.g., end-users or suppliers) in the product innovation process. These workshops help to reveal a maximum of radically new ideas, improve an existing product, or solve a technical problem (Brem, 2019). At the Mercedes-Benz AG, the Innovation Studio specializes in planning and conducting ideation workshops. Per year, the Innovation Studio hosts 50 to 80 workshops (Figure 5.1.1).

Figure 5.1.1. Impression of the Innovation Studio.

The practical guidelines for how to plan and run an ideation workshop successfully are numerous. Such guidelines describe an *ideal* process, which has to be adapted to the present context, product, or problem space. Brem (2019), for example, has presented a structured approach to ideation workshops tailored to industrial research and development departments. Before the workshop, the topic, a specific research question, the location, necessary materials, the duration, and the group composition of the workshop are determined. A workshop takes at least two to four hours and has a maximum of two days. Usually, a workshop group includes five to seven participants. If there is a larger group, it is recommended to separate the participants into subgroups. The group should consist of individuals with diverse backgrounds to consider the topic from different perspectives, but with some commonalities to make it easier for them to collaborate. According to Brem (2019), an ideation workshop follows a general structure that is enriched with different creativity methods, including free association tasks (e.g., brainstorming), structured association tasks (e.g., Walt Disney method), configuration techniques (e.g., attribute listening), confrontation techniques (e.g., buzzword analysis), or imagination techniques (e.g., fantasy journeys). Each workshop should start with a personal and professional entry. Following, the core workshop consists of five phases: idea collection, idea generation, idea consolidation, idea evaluation, and idea elaboration. In the collection phase, participants recapture their existing associations with the workshop topic using association tasks. In the generation phase, they are encouraged to come up with new or unknown ideas with the help of confronting, configuration, and imagination techniques. Following, all material the participants produced during the workshop is consolidated by collecting it in one place. In the evaluation phase, the ideas are prioritized and selected. This can be done by involving the workshop participants (e.g., visual voting or colored dots) or other people who are not operatively involved in the workshop but, for example, responsible for its funding. Finally, participants have the possibility to further elaborate on their idea(s) by conceptualizing and prototyping them. The final ideas and prototypes are presented to the other participants and relevant stakeholders. The workshop should close with a feedback round in which participants can share their suggestions and criticism regarding the workshop (Brem, 2019).

This chapter describes a series of ideation workshops that are aimed at generating technology-based ideas to mitigate aggressive driving. Thereby, the empirical findings revealed so far, i.e., the triggers of aggressive driving and the anti-aggression interventions, are taken up and transformed into tangible solutions.

5.2 Study 3: Ideation Workshops

Under the title “ideas against anger and aggressions behind the wheel,” six ideation workshops were run in order to generate innovative ideas to mitigate aggressive driving. Each workshop took place at the Mercedes-Benz Innovation Studio, which provided the perfect environmental and material conditions for the purpose of ideation.

After the workshop days, the generated ideas were evaluated by innovation experts from the automotive domain.

5.2.1 Method

Sample

All workshop participants were employees of the Daimler Group. Six workshop days were offered to give a large number of people the chance to take part during their daily work hours. The proposed dates were announced via an email invitation. The invitation was distributed within internal departments that were supposed to be concerned with the issue of aggressive driving (e.g., driver assistance systems, navigation, or safety functions). The recipients were asked to choose one of the six appointments and to forward the email to colleagues. In doing so, 546 email invitations were initially sent out.

In total, 108 participants took part in the six workshops (session 1: 19; 2: 16; 3: 20; 4: 14; 5: 21; 6: 18), of which 57 were male and 51 were female. Their age ranged from 20 to 63 years, with a mean of 34.5 (SD = 10.1). Out of the participants, 29.6 percent had never attended a workshop at the Innovation Studio before. Around half of them (50.9%) had already participated in a workshop between one and five times, 5.6 percent between six and ten times, and 13.8 percent over 20 times.

Procedure

Each workshop was scheduled for three hours and followed the same agenda, as depicted in Figure 5.2.1.

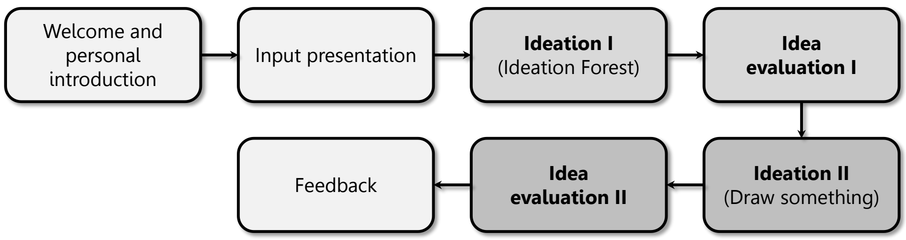


Figure 5.2.1. Structure of the ideation workshops.

First, participants were welcomed by the workshop team (i.e., the author and three students working at the Innovation Studio) and introduced themselves to each other. They were then convened in the forum of the Innovation Studio where they listened to a 15-minute presentation on the consequences, triggers, and treatment of aggressive driving based upon previous research (Figure 5.2.2).

Figure 5.2.2. Forum of the Mercedes-Benz Innovation Studio.

Each workshop included two ideation sessions using different self-developed creativity methods. The first was called *Ideation Forest* (Figure 5.2.3). For this, the hall was transformed into a forest by randomly arranging meta-plan boards printed with trees. On each board, a question on aggressive driving was depicted that was previously brainstormed by the workshop team (e.g., “Why do I swear out loud in the car but not at the supermarket cash register when things take too long?”). Participants walked through the forest and answered as many questions as they wanted by writing on the boards. Then, they selected a single answer and generated an idea inspired by this thought. They wrote their idea, on a one-pager including title, description, context of use, and challenges (Appendix 3.1). Afterward, all ideas were presented one after the other in a 30-second pitch to the other participants. During the pitch, the audience evaluated the ideas according to the criteria (i) attractiveness of the design, (ii) level of novelty, (iii) personal usefulness, and (iv) business feasibility using the labels “very low” (1), “low” (2), “medium” (3), “high” (4), and “very high”

(5; Justel et al., 2007). For this, an evaluation form was prepared (Appendix 3.2).

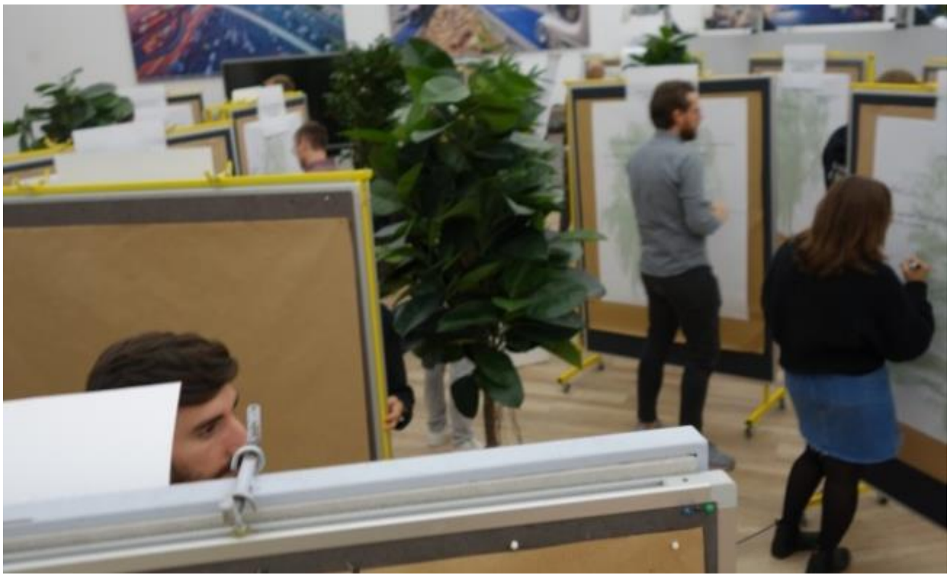


Figure 5.2.3. Impressions of the creativity methods “Ideation Forest”.

The second creativity method was called *Draw something*. For this, four containers with different types of notes were prepared: (i) personas, (i) types of drivers, (ii) triggers of aggression while driving, and (iii) interventions to mitigate human aggression (Figure 5.2.4). The personas were created by the workshop team in a previous brainstorming session (e.g., a mother driving with her child in the backseat, an old married couple, or a trucker). The driver types were based on Taubman-Ben-Ari, Mikulincer, and Gillath (2004), who propose eight different driving styles (e.g., angry driving, high-velocity driving, or patient driving). The triggers (e.g., frequent red lights, slow vehicle ahead, or bad weather) and interventions (e.g., breathing, haptic stimuli, or team spirit) were derived from the research conducted so far in this thesis. In pairs of two, participants drew a note from each container and generated an idea by combining the information. Again, the ideas were written on one-pagers, presented to the other participants, and evaluated by the audience. After this ideation session, the workshop concluded with a feedback round and a paper-pencil questionnaire to capture background information about the participants (i.e., gender, age, and the number of workshops attended at the Innovation Studio).

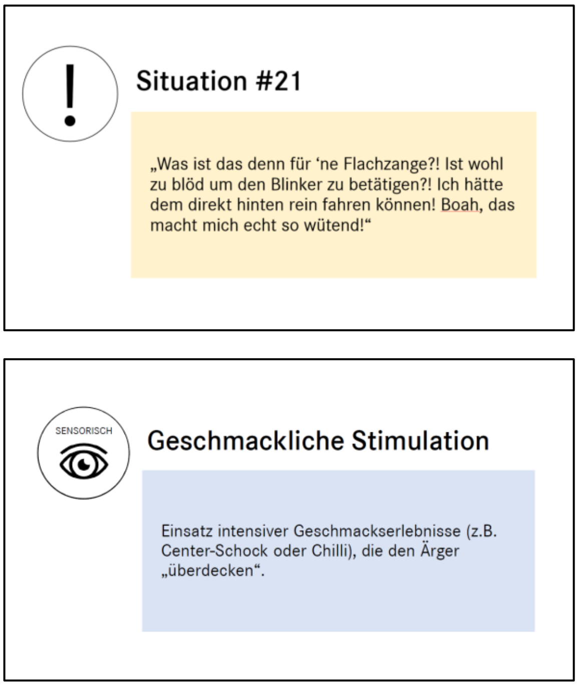


Figure 5.2.4. Examples of notes of aggressive triggers (top) and interventions (bottom).

Expert Evaluation

In total, 164 idea one-pagers were generated in the six workshops. After the workshop days, all ideas were evaluated by four experts. All experts were employees of the Innovation Studio, with one belonging to the management level. Two experts (including the author) were specialized in customer research. The other two experts provided special expertise on product innovation processes. Like the workshop participants, the experts evaluated the ideas in terms of the (i) attractiveness of the design, (ii) level of novelty, (iii) personal usefulness, and (iv) business feasibility of the ideas. The criteria were assessed on a scale with the labels “very low” (1), “low” (2), “neither nor” (3), “high” (4), “very high” (5; Justel et al., 2007). By calculating the mean of these criteria, the innovative potential of the ideas was determined. For the expert evaluation, a CSV-based questionnaire was prepared, including the transcribed one-pagers. The experts filled in the questionnaire individually. According to them, two of the one-pagers did not describe an idea, so these were eliminated from further analysis. For the remaining 162 ideas, the intra-class correlation coefficient of the expert ratings was calculated using a two-way mixed-effects model (Koo & Li, 2016). Unfortunately, the values are indicative of poor reliability when considering the criteria assessed individually, i.e., $ICC_{Attractivness}$ = .32, $ICC_{Novelty}$ = .38, $ICC_{Feasibilty}$ = .50, and $ICC_{Usefulness}$ = .32. In addition to the expert evaluation, the ideas were clustered by the author of this thesis.

5.2.2 Results

In the following, the results of the expert evaluation and the idea clusters are reported. In order to protect the rights of the idea creators, the individual ideas are not described in detail but by means of their title and the clusters to which they were assigned.

The 162 ideas can be grouped into nine different clusters: (i) affect-adaptive telematics, entertainment, and comfort functions (51 ideas), (ii) communication with other road users (27), (iii) gaming and gamification applications (24), (iv) affect-sensitive driving assistance systems (18), (v) empathetic in-car agent (15), (vi) relaxation and physical activity (12), (vii) task and time management while driving (6), (viii) advanced navigation (5), (ix) and emotion recognition methods (4). The last cluster describes technical enablers that are used to automatically recognize the driver's affective state, for example, by analyzing physiological signals, driving data, gaze movements, and facial or verbal expressions. However, the ideas of this cluster do not describe a specific idea of how this technology might be used to mitigate aggressive driving. Thus, these ideas are not considered further. The remaining eight clusters are briefly described below.

- **Affect-adaptive telematics, entertainment, and comfort functions:** this cluster includes ideas that use the existing in-car features, such as displays, ambient light, massage seats, air conditioning, music and sound, fragrances, or even surfaces. If the vehicle detects a negative emotional state, it adapts these channels so that they have a calming effect on the passengers. The participants named their ideas, for example, "Rolling Comedian," "Beautiful Memories," or "Cool-down Entertainment."
- **Communication with other road users**: the ideas of this cluster support road users in exchanging personal and traffic-related

information (e.g., sociodemographic data or emotions) or participating in collaborative activities (e.g., playing a game or relaxation exercises) by using vehicle-to-vehicle communication. Ideas in this category bore titles such as "Common Interest Indicator," "Navigation-based Driver Community," or "Show your Emotions."

- **Gaming and gamification applications**: the applications refer to games that drivers or passengers can play while driving or standing (e.g., during a red phase or traffic jam). In contrast to the communication cluster, these games are not aimed at being played with other road users. Corresponding ideas were called "Traffic Jam Tinder," "Driving Safety Score," or "Red Traffic Light Quiz."

- **Affect-sensitive driving assistance systems:** this type of driving assistance systems attempts to correct inappropriate driving behavior (e.g., blocking the far left lane or speeding) that occurs under the influence of negative emotions. If a negative emotional state of the driver is detected by the system, he is either explicitly informed of his misconduct or the driving assistance systems are automatically adapted so that traffic violations are prevented (e.g., a higher distance setting on the adaptive cruise control). Exemplary ideas included "Drive-on-the-Right-Lane-Assistant," "Mindful Driving," or "Be-Nice-Assistant."

- **Empathetic in-car agents**: the aim of empathetic agents is to replace a human co-driver, who calms the driver down. Empathetic agents are characterized by their intelligent and social interaction style. Most of the ideas are based on verbal communication and had names such as "Stress Buddy" or "Talk Master 2000."

- **Relaxation and physical activity:** if the driver is stressed, the systems of this category can function in two ways. On the one side they can provide guidance on relaxing or activating activities that can be performed in the car (e.g., "Get Fit"). On the other side, they can activate in-vehicle comfort function with a calming effect (e.g., "Whole Body Relaxation Program").

- **Task and time management while driving:** the ideas support the driver in making better use of time in the car and, therefore, reduce the feeling of time pressure. This is done by features that make it possible to write emails, manage appointments, or have a meeting while driving. Examples are the "Sorry-too-late-messenger" or the time management tool "Stress-free Trip."

- **Advanced navigation:** advanced navigation functions guide the driver through routes that are supposed to elicit positive emotions. These ideas have titles such as "Driving Flow Supporter," "Navi on Demand," or "Off-road Alternative Route."

Overall, the 158 relevant ideas had only medium innovative potential. The mean was 2.98 (*SD* = .30), which is close to the mean of the scale (*M* = 3.00). Looking at the individual criteria, the ideas were assessed as only moderately useful (*M* = 3.11, *SD* = .47), attractive (*M* = 2.97, *SD* = .50), novel (*M* = 2.95, *SD* = .53), and feasible (*M* = 2.89, *SD* = .61). On the cluster level (Table 5.2.1), the ideas with the highest innovative potential were in the cluster "task and time management while driving" (*M* = 3.27, *SD* = .65), followed by "advanced navigation" (*M* = 3.22, *SD* = .58) and "affect-sensitive driving assistance systems" (*M* = 3.04, *SD* = .48). "Task and time management" ideas also received the highest ratings in terms of attractiveness (*M* = 3.50, *SD* = .87) and usefulness (*M* = 3.79, *SD* = .91). The most feasible ideas were related to "advanced navigation" (*M* = 3.45, *SD* = 1.12) and the most novel ones to "communication with other road users" (*M* = 3.25, *SD* = .95).

Table 5.2.1. Expert evaluation of idea clusters.

	M (SD)				
Cluster	**Attractive**	**Useful**	**Novel**	**Feasible**	**Innovative**
Task and time management	3.50 (.87)	3.79 (.91)	2.38 (1.22)	3.42 (1.08)	3.27 (.65)
Advanced navigation	3.10 (.77)	3.10 (.94)	3.16 (1.04)	3.45 (1.12)	3.22 (.58)
Driving assistance systems	2.83 (.83)	3.42 (.83)	3.21 (.90)	2.69 (.94)	3.04 (.48)
Gaming and gamification	3.11 (.90)	2.93 (.82)	3.22 (1.06)	2.86 (.95)	3.03 (.54)
Empathic in-car agent	3.05 (.72)	3.23 (.69)	2.95 (1.02)	2.78 (.88)	3.00 (.62)
Relaxation and activity	2.87 (.82)	3.17 (.75)	2.64 (1.06)	3.28 (.79)	2.99 (.54)
Telematics, entertainment, and comfort functions	2.98 (.84)	3.06 (.75)	2.72 (1.12)	3.15 (.81)	2.98 (.54)
Communication	2.82 (.83)	2.94 (.71)	3.25 (.95)	2.28 (1.08)	2.82 (.50)

N = 4; scale: 1 "very low" – 5 "very high"

Looking at the distribution of the innovative potential of the individual ideas, 95 percent received a value below 3.50 (25th percentile: 2.75, 50th percentile: 3.00, 75th percentile: 3.19, *min*: 1.92, *max*: 3.56; Figure 5.2.5). The five percent of ideas with the highest innovative potential were "Empathic Car" (*M* = 3.56, *SD* = .55, cluster: empathic in-car agent), "Stress-free Trip" (*M* = 3.56, *SD* = .69, cluster: task and time management), "Redirect Attention" (*M* = 3.50, *SD* = .58, cluster: task and time management), "Mindful Driving" (*M* = 3.50, *SD* = .41, cluster: relaxation and activity), "Beautiful Memories" (*M* = 3.50, *SD* = .35, cluster: telematics, entertainment, and comfort functions), "Car Quiz" (*M* = 3.50, *SD* = .54, cluster: gaming and Gamification), "Mercedes-Benz Community" (*M* = 3.50, *SD* = .29, cluster: communication), and "Drive-on-the-Right-Lane-Assistant" (*M* = 3.50, *SD* = .58, cluster: driving assistance systems).

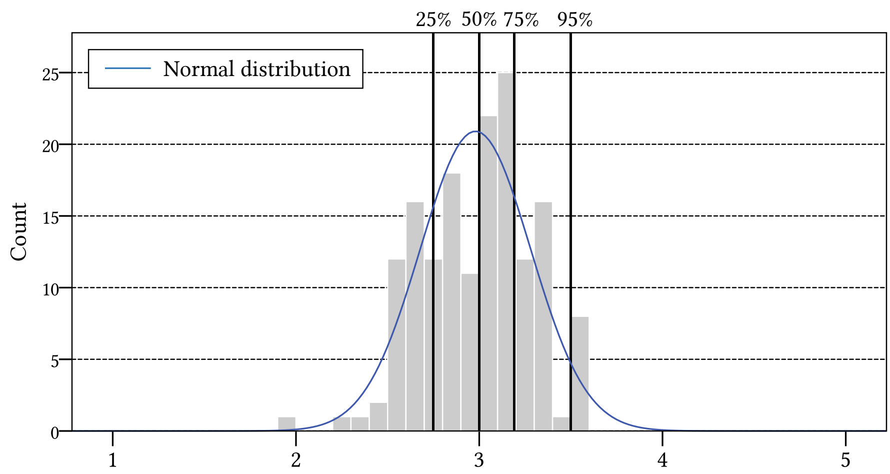


Figure 5.2.5. Percentiles and distribution of the innovative potential of the ideas.

5.2.3 Conclusion and Discussion

The previous sections described a series of six ideation workshops that were conducted to generate innovative ideas of Persuasive Technology to mitigate aggressive driving. The workshops, in which 108 participants took part, revealed 158 relevant ideas that were evaluated by an expert sample in terms of the (i) attractiveness of their design, (ii) level of novelty, (iii) personal usefulness, and (iv) business feasibility. Based on these criteria, the innovative potential of the ideas was calculated. In addition, the ideas were assigned to eight relevant clusters: (i) affect-adaptive telematics, entertainment, and comfort functions, (ii) communication with other road users, (iii) gaming and gamification applications, (iv) affect-sensitive driving assistance systems, (v) empathetic in-car agent, (vi) relaxation and physical activity, (vii) task and time management while driving, (viii) advanced navigation. Overall, the innovative potential of the ideas was only moderate, which suggests that the workshops did not produce particularly innovative ideas.

In practice, however, it is not uncommon that, despite all efforts, ideation workshops and other creativity methods do not result in innovative outcomes, underpinning the consensus that innovation on demand is hard to achieve (Ovington et al., 2018). In the present case, the lack of innovation could be explained by the fact that the final workshop phase—the idea elaboration—was omitted (Brem, 2019). Another methodological limitation is the low degree of agreement between the experts regarding their evaluation of the ideas, which may be due to their different perspectives. For example, a manager responsible for the economic success of a company will focus on the business feasibility of an idea; a user researcher will place special emphasis on its usability; and an expert concerned with product innovation processes, will be more critical when it comes to its novelty. These priorities could have counterbalanced each other, which would explain the moderate innovation potential of the ideas. Nevertheless, one should not forget that experts do not reflect the opinion of the masses and that an idea can still turn out to be a success on the market.

Despite the moderate evaluation of the ideas, the workshops revealed thought-provoking impulses that might inspire the further elaboration of a persuasive system solution to mitigate aggressive driving. Here, special focus should be placed on the core concepts behind the identified idea clusters. They emphasize, for example, the importance of time (cluster “time and task management while driving”), the role of the car as a human-like co-driver (cluster “empathic in-car agent”), or the car as a place of retreat (cluster “relaxation and activity”).

VI. CHAPTER

ELABORATION OF THE DRIVING FEEDBACK AVATAR

6.1 Background

The results of the ideation workshops are full of inspiring impulses for the development of a persuasive system solution to mitigate aggressive driving. The perspective that was most inspiring for the future system was the one of an empathetic in-car agent that attempts to calm the driver down. This chapter explains why this perspective stands out from the state of the art and how it was elaborated on. As a result of this elaboration process, a concrete system concept with design and technical specifications is presented: the *Driving Feedback Avatar*.

What characterizes the idea of an empathetic in-car agent is its intelligent and social nature. In contrast, most of the other workshop ideas are technology-driven and focus on functional purposes, such as saving time, exchanging information, or improving driving performance. The idea of a car with intelligent and social features contributes to the trend of the car as a human-like co-driver (Eyben et al., 2010; Wiese, Shaw, Lofaro, & Baldwin, 2017). It is commonplace for people to name their cars, talk to them, or equip them with personal belongings, all of which are manifestations of the social relationship people have with their cars. With the arrival of artificial intelligence, the car of the future could encourage this social interaction by using natural language, recognizing and expressing emotions, or adopting non-verbal communication patterns such as eye and head movements (Wiese et al., 2017). Elaborating on the idea of an intelligent and social in-car agent that attempts to calm the driver down, the following questions arise: what could such an agent look like and which intervention should be used to calm the driver down?

The first question asks for the embodiment of the agent so that it can be seen, heard, or sensed by drivers and passengers (Pfeifer & Iida, 2003). "Embodiment is an inherent property of an agent that exhibits intelligent behaviour leading to the now established hypothesis that, in order to achieve cognitive capabilities or a degree of intelligence in an agent, a notion of embodiment is required" (Duffy & Joue, 2000, p. 28). Thereby, the agent does not need to have a physical form to reach a certain degree of embodiment. Manifested in the theory of mind, non-physical attributes, such as a voice or a name, can also trigger the mental projection of intelligence and social competences on non-human entities (Zarkadakis, 2016). In section *2.3 Related Work: In-car Interfaces,* some examples of embodied in-car interfaces were already given, including visual and auditory representations. The design approach that significantly influenced the design of the future system is described in section *6.2.3 Avatar and Feedback Design.*

The second question can be answered by reviewing the anti-aggression interventions identified in *chapter IV.* Among these, situation reflection is examined in more detail. According to this intervention, aggression can be regulated by making the aggressor aware of his emotional state. One reason for focusing on this intervention is that the principle of situation reflection is also used by feedback-based systems that have been demonstrated to have a positive effect on behavior change in the context of driving (*2.3 Related Work: In-car Interfaces*). Theoretically, feedback is a performance indicator based on the outcome of a behavior (Wilson, Bhamra, & Lilley, 2015). By providing the individual with feedback on his performance, he can make associations between the behavior and its consequences. This association may initiate the evaluative reflection of the behavior, which, in turn, may lead to behavior change. Many feedback systems—inside and outside the context of driving—use avatars or other abstract representations to transmit the feedback information (Figure 6.1.1). For example, visual feedback systems to foster ecological driving represent the driving performance by the growth level of a plant. Health applications, such as drink reminders, use plant-like metaphors to visualize an individual's health status. Also, the Tamagotchi is an example of an avatar-based feedback system. Here, the focus is on one's care-taking behavior. The Tamagotchi is a "tiny pet from cyberspace who needs your love to survive and grow. If you take good care of your Tamagotchi pet, it will slowly grow bigger, healthier, and more beautiful every day. But if you neglect your little cyber creature your Tamagotchi may grow up to be mean or ugly" (Schlatz, 2014).

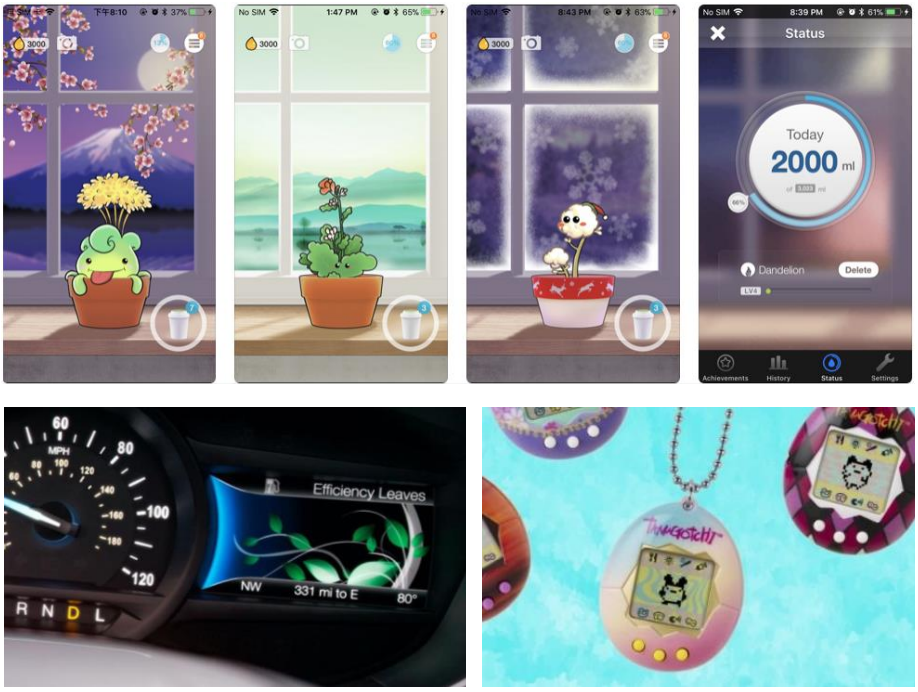


Figure 6.1.1. Drink reminder application Plant Nanny (top; Fourdesire, 2014), Ford eco interface (bottom left; Ford, 2016), and the Tamagotchi (bottom right; Schlatz, 2014)

Concluding the previous considerations, the future system is supposed to be an intelligent and social in-car agent with some kind of embodiment. The purpose of the system is to give the driver feedback on his driving behavior—with a special focus on aggressive driving—so that he voluntarily drives less aggressively. The system is called Driving Feedback Avatar (DFA).

6.2 Conceptualization

In the subsequent sections, the basic idea of the DFA is shaped into a concrete concept. For this, the following aspects are specified: (i) the aggressive driving behaviors that are fed back, (ii) the rules according to which the feedback is given, and (iii) the design of the avatar and the feedback. Moreover, the theoretical foundations on which the assumed persuasiveness and effectiveness of the system are based are introduced. The technical principle of the DFA is patented (Patent No. DE10 2019 003 623.9, 2020).

6.2.1 Aggressive Driving Behaviors

In order to determine the behaviors the DFA should consider, common questionnaires regarding the expression and perception of aggressive driving were reviewed. These questionnaires provide concrete descriptions of behaviors that may be relevant. In line with the variety of definitions of aggressive driving, a corresponding number of questionnaires emerged. For example, understanding aggressive driving as an intentional act to harm, Dula and Ballard (2003) developed the *Dula Dangerous Driving Index* that includes scales for risky driving (e.g., "I will cross double yellow lines to see if I can pass a slow moving car/truck"), negative cognitive/emotional driving (e.g., "I consider the actions of other drivers to be inappropriate or stupid"), and aggressive driving (e.g., "I flash my headlights when I am annoyed by another driver"). Focusing on hostile driving and road rage, Özkan and Lajunen (2005) proposed the *Driver Aggression Indicator Scale* that differentiates between hostile aggression and revenge (e.g., "hugged the rear bump") and aggressive warnings (e.g., "made a hand gesture"). Defining aggressive driving as a pattern of unsafe driving, Harris, Houston, Vazquez, Smithers, and Harms (2014) presented the *Prosocial and Aggressive Driving Inventory*, measuring safe driving behaviors (e.g., "obey traffic signs") and unsafe driving behaviors (e.g., "drive 15 miles per hour faster than the posted speed limit"). Finally mentioned, the *Perception of Aggressive Driving Scale* incorporated different scales of existing questionnaires, considering behaviors such as "shouting and cursing," "not signaling turns and lane changes," or "sudden and frequent change of lane" (Alonso, Esteban, Montoro, & Serge, 2019).

After summarizing the behaviors reported in these questionnaires, they were checked against two criteria: (i) the possibility of automatic detection using vehicle sensors (e.g., cameras, radar, or microphones) and artificial intelligence (e.g., face or gesture recognition) and (ii) the probability of occurrence on the highway. Due to the first criterion, behaviors that are characterized by the driver's intent were excluded. Intentions are hypothetical states that cannot be observed but have to be *inferred* from overt behavior (Houston et al., 2003). For instance, in the case of the behavior "follow the vehicle in front of me closely to prevent another vehicle from merging in front of me" the assumed intent is to prevent another driver from merging in (Harris et al., 2014). However, another reason for a short following distance could be that the driver is in a hurry or that he misjudges distance's criticality. The second criterion describes the initial use case of the system. The choice for this road type was mainly driven by the fact that, due to high velocity, accidents resulting from aggressive driving tend to be particularly severe on the highway (European Commission, 2018). As a result, the following nine aggressive driving behaviors were considered relevant for the conceptualization of the DFA:

(1) Tailgating
(2) Exceeding the speed limit
(3) Not using the indicators before changing lanes
(4) Using the indicators shortly before changing lanes
(5) Verbally insulting other road users
(6) Making insulting gestures toward other road users
(7) Flashing headlights at a slower vehicle
(8) Changing in one go from the right lane to the very left lane (on a road with at least three lanes)
(9) Passing a single continuous center line

6.2.2 Feedback Algorithm

To get a better idea about the functionality of the DFA, one could remember the Tamagotchi. The emotional state of the Tamagotchi pet depends on the user's care-taking behavior. In the case of the DFA, the pet is replaced by an in-car avatar that has the capacity to express emotions. The emotional state of the avatar relates to the user's driving behavior. What this avatar looks like, is described in the following section *6.2.3 Avatar and Feedback Design.* For now, it is enough to know that the driver can take care of the avatar by *not* driving aggressively. This means that if the driver shows no aggressive driving behavior, the avatar "feels good" and expresses a positive emotion (positive feedback). In contrast, if the driver drives aggressively, the avatar "feels bad" and shows a negative emotion (negative feedback).

Severe driving violations have a stronger negative impact on the avatar's well-being than milder ones. Thus, technically, the feedback algorithm is an integral function based on the frequency of each detected relevant aggressive driving behavior and its severity. Both factors are multiplied and summed up over the elapsed driving time. The result of this function is an aggressive driving score. The score is adapted every time an aggressive action is detected and constantly mapped on the emotional state of the avatar. If the upper (or lower) level of the current state is reached, the avatar changes to the next state. Thus, the avatar's emotional state changes gradually.

Important to note, the DFA does not actively provide positive feedback on prosocial driving. This decision is based on a study conducted by Byrne et al. (2012), who investigated the effect of positive and negative feedback provided by a Tamagotchi-like avatar on the likelihood to eat breakfast. For this purpose, the smartphone game *Time to Eat* was developed. In the game, the player chooses a pet avatar (e.g., dog, dinosaur, or penguin) from which he receives a message each morning, prompting him to eat breakfast and send a picture of the meal. Depending on the meal's healthiness, each picture receives a score based on which the pet appears very unhappy, mildly unhappy, neutral, mildly happy, or very happy. In a field experiment, 53 adolescents playing the game were asked to send a photo under one of three conditions: (i) from the pet giving negative and positive feedback, (ii) from the pet giving neutral and positive feedback, or (iii) from a designated mail address without feedback. As a result, participants with a pet that expressed positive *and* negative emotions were twice as likely to eat breakfast, relative to participants with a pet that gives no negative feedback and participants of the no-pet condition. Additionally, participants exposed to negative emotions were more attached to the pet and had a better gaming experience than those whose pet only expressed positive emotions.

6.2.3 Avatar and Feedback Design

Design Options

The design of the DFA was guided by the PIDAF that is detailed in section *2.2.2 Behavior Change through Persuasive Technology: Persuasive Interface Design Framework in the Automotive Domain*. The nine design options proposed within this framework are specified for the DFA.

- **Modality:** auditory or haptic information quickly captures the driver's attention and is mainly used if an immediate response is required (Campbell et al., 2016). Both feedback modalities increase not only perceived urgency but also annoyance, neither of which should be caused by the DFA (Marshall, Lee, & Austria, 2007). Thus, the decision was made in favor of a visual interface.

- **Placement, integration, mobility, and ambience:** displays are the major device to provide visual information in the car. Considering the available in-car displays, the DFA might be integrated into the center console display, the instrument cluster, or the head-up display. While the first option places the system in the periphery, the last two options put the system closer to the driver's field of view. As a general principle, the higher the priority of information the closer it should be located to the driver's vertical viewing position. Priority is based on the information's relevance for the primary driving task (i.e., controlling and navigating the car), criticality, urgency, and frequency of use (Burns, Andersson, & Ekfjorden, 2000). However, none of these criteria applies to the information given by the DFA so that a peripheral solution was pursued. A mobile solution was not considered in the first step.
- **Feedback and frequency:** basically, there are two types of feedback: instant and delayed feedback. Instant feedback is provided directly after a relevant behavior has occurred. It is supposed to have a greater impact on changing the behavior in question, relative to delayed feedback, because it strengthens the cognitive link between the behavior and its consequences and creates an awareness of the behavior. Delayed or summative feedback is mainly used to summarize performance and to monitor progress over time (Wilson et al., 2015). To increase the effectiveness of the DFA, a combined solution, integrating both instant and summative feedback, was pursued (Addalena & Aras, 2005).
- **Representation and visualization:** information displayed in an in-car interface can be concrete and metaphorical. The decision was made for the latter by representing the driver's performance through the emotional state of the avatar since metaphorical feedback is most efficient in the context of driving. For example, Dahlinger, Wortmann, Ryder, and Gahr (2018) compared a tree that was growing depending on the driver's fuel consumption (metaphorical feedback; Figure 6.2.1) with a numerical score representing the same information (concrete feedback). Only the metaphorical feedback caused a significant reduction in fuel

consumption. There is a (theoretically) infinite variety of emotional states so the feedback given by the DFA is continuous by nature.

Figure 6.2.1. Concrete (left) versus abstract (right) eco driving feedback (Dahlinger et al., 2018)

Final Design

For the automotive industry, the embodiment of artificial intelligence is a current hot topic. At Mercedes-Benz, first design concepts to visualize a car's intelligence were developed. The concept that provided the basis for the DFA is an abstraction of the Mercedes-Benz star, the hallmark of the brand (Figure 6.2.2.). This abstract star constitutes the avatar of the system. Important to note, the design concept is a working prototype used for internal research and development activities and does not hold the claim for series implementation.

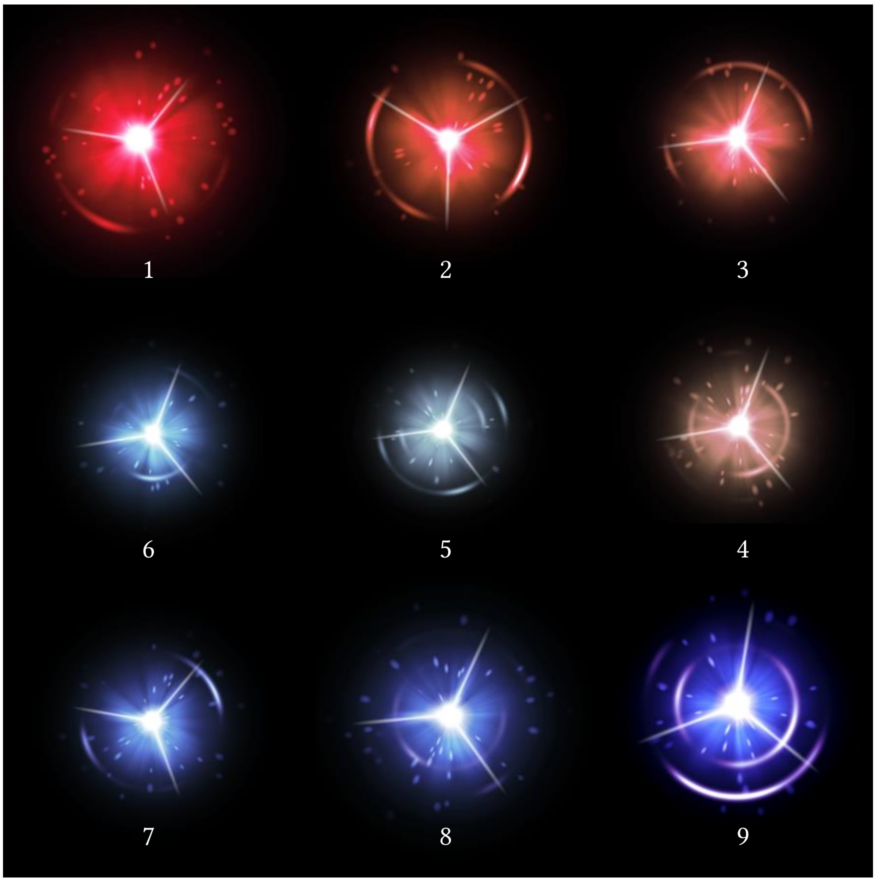


Figure 6.2.2. Visualization of the DFA and its emotional states.

In order to express different emotional states, the avatar was animated in terms of color and motion. In doing so, nine different states were modeled, ranging from negative to neutral to positive. Inspired by Byrne et al. (2012), the positive pole is represented by the emotional state of relaxation, the negative pole by anger. These states were modeled based on findings from color associations and work dealing with the assignment of physiology in systems. For example, anger is most likely associated with red, while the most common associations with relaxation are green and blue. There is also a positive correlation between the saturation of a color and the physiological arousal it evokes (Clarke & Costall, 2008). Thereby, relaxation is associated with a medium level of arousal, while anger is a typical high-arousal emotion. Physiological arousal, in turn, is linked to the frequency rates of physiological reactions, such as heart rate and blood pressure, body temperature, or respiration (Peter & Herbon, 2006; Scherer, 2005). Consequently, for the anger-related states (stage 1 to 4) tones from the red color spectrum were used, while the states associated with relaxation (stage 6 to 9) were represented by tones of blue. The closer the states are to the poles, the higher their color saturation so that the avatar appears grey in the neutral state (stage 5). On the dynamic dimension, the avatar shows pulsating movements corresponding to the arousal of the intended emotional state. Movement frequency is highest at the anger pole (stage 1) and gradually decreases until it reaches the neutral state (stage 5), where there is little movement. From the neutral state to the relaxation pole (stage 9), movement frequency increases again but remains below the frequency of the anger pole. In other words, the redder (or bluer) the avatar appears, and the faster it moves, the more negative (or positive) the feedback is. The avatar's state changes by degrees when the upper (or lower) threshold of the current state is reached. It is important to note that the avatar does not respond to or reflect the driver's emotions but expresses an intrinsic emotional state.

The emotional state of the avatar is a summarized assessment of the driver's performance. In addition, instant feedback was implemented into the DFA in the form of a visual alert occurring at the moment an aggressive action is recognized (Figure 6.2.3). For this, the background of the avatar animation flashes two times per second, changing its color from black to orange (Chan & Ng, 2009).

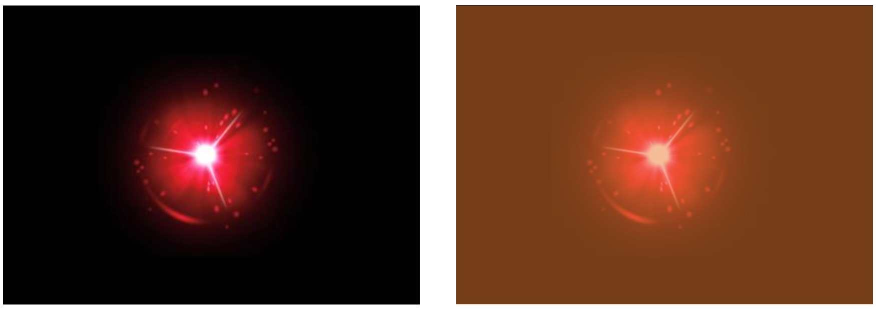


Figure 6.2.3. Instant feedback given by the DFA.

Manipulation Check

To check (i) whether the emotional states of the avatar are perceived according to the intended valence (positive vs. negative) and (ii) whether the feedback design is perceived as emotional at all, four participants (2 female, 2 male) completed a free association task. In random order, videos of the nine states were each shown to the participants and they were asked about their first impression. The emotional terms and expressions reported were grouped according to their semantical similarity by the author. The negative feedback states were mostly associated with negative terms and expressions such as "alarm, danger, emergency, attention," "blood, heartbeat, pulse," or "aggressive, rage, anger." The positive feedback states were mainly described with positive words such as "cold, ice, water, fresh," "positive, enjoyable, friendly," or "calming, relaxing." The most common associations with the neutral state were "slow," "dead, stand by, nothing happens," and "neutral, normal." As these examples show, the participants used various emotional terms and expressions to describe the avatar's states and inferred the right emotional valence from the colors and movements programmed into the avatar.

6.2.4 Theoretical Foundations

In reference to Shinar (1998), the DFA attempts to change the driver's behavior directly by triggering his situation reflection. If the driver drives less aggressively, he cannot be a trigger of aggression for other driver, which changes their behavior indirectly. Beyond this theoretical foundation, there are further considerations addressing the persuasiveness of the DFA, including (i) the paradigm of raising awareness (Lutfi Bin Dolhalit, Nur Binti Abdul Salam, & Bin Abdul Mutalib, 2016), (ii) the persuasive power associated with the gamified nature of the system, and (iii) the emotional attachment caused by the emotionality of the avatar (Frude & Jandrić, 2015; Lawton, 2017).

Awareness

The main purpose of feedback systems is to raise the user's awareness of an undesired behavior that is intended to be changed as awareness gives impulses for reflection. Although awareness toward a certain behavior or issue does not necessarily result in behavior change, it is a main driver of it (Lutfi Bin Dolhalit et al., 2016). Especially persuasive systems that are seen as social actors or those that provide a compelling simulated experience of the behavior in question have the potential to increase awareness (Lutfi Bin Dolhalit et al., 2016). The DFA serves both requirements. On the one side, the system can be seen as a social actor that is able to express human-like emotions. On the other, it simulates a living being in the form of the avatar (Fogg, 2003).

Gaming Experience

Avatars and feedback are typical game elements. With the DFA, they are used in a non-game environment, which refers to the concept of Gamification, i.e., "the use of game design elements in non-game contexts" (Deterding et al., 2011, p. 9). The goal of Gamification is to motivate people to change behaviors in a playful and voluntary manner, which is why gamified systems are inherently persuasive (Werbach, 2015). The playfulness derives from the gaming experience associated with the use of the system, including subjective experiences such as immersion, flow, competence, positive and negative affect, tension, and challenge (Ferrara, 2013; Poels, de Kort, & IJsselsteijn, 2013). With the DFA, the driving task is gamified by linking it to the challenge of taking care of the avatar's emotional state.

Emotional Attachment

What distinguishes the DFA from existing feedback systems is its emotional nature. The attribution of human-like characteristics, including emotions, physical attributes, intentions, or motivations to non-human objects, refers to the concept of *anthropomorphism* (Bartneck, Croft, & Kulic, 2009; Richert, Müller, Schröder, & Jeschke, 2018; Yuan & Dennis, 2019). According to the *Tamagotchi effect,* the attribution of emotions to technology increases the user's emotional attachment to the system (Frude & Jandrić, 2015; Lawton, 2017; Turkle, Taggart, Kidd, & Dasté, 2006). If people feel attached to a system, this promotes their care-taking behavior toward it, and—vice versa—if people care about technology, they may become attached to it. Besides the effect on the driver's duty of care, emotional attachment also improves the persuasiveness of the DFA in other ways.

First, a general problem of feedback systems is the issue of *psychological reactance*. Psychological reactance can be explained as follows: "if a person's behavioral freedom is reduced or threatened with reduction, he would become motivationally aroused. This arousal would presumably be directed against any further loss of freedom and the reestablishment of whatever freedom had already been lost or threatened" (Brehm, 1966, p. 2). The unpleasant motivational state of reactance causes affective, behavioral, and cognitive reactions of the individual that are aimed at reestablishing his freedom. On the affective level, people who are threatened may feel uncomfortable, hostile, aggressive, or angry. On the behavioral level, they may enact the restricted behavior or behave in an aggressive way to reassure themselves. On the cognitive level, they may change the perceived severity of the threat, the relevance of restricted freedom, or the attractiveness of the alternative (Steindl, Jonas, Sittenthaler, Traut-Mattausch, & Greenberg, 2015). Also technology can be threatening, for example, when system errors occur or false information is given. In such situations, people typically tend to react by rejecting the system (Ehrenbrink & Prezenski, 2017). The feedback given by the DFA might be threatening if it is perceived as unfair or criticizes the driver's skills (Uludag, 2014), if it causes the feeling of being patronized (Spiekermann & Pallas, 2006), or if the driver does not understand what he is getting the feedback for (Bar-Anan, Wilson, & Gilbert, 2009). However, if the feedback is provided by an entity, whether human or technical in nature, to which the recipient of the feedback feels attached, the advice is more likely to be accepted. For example, YouTube advertising produced by a peer is more effective in creating positive attitudes toward the advertised product than announcements from expert producers to whom the recipients have no connection (Paek, Hove, Ju Jeong, & Kim, 2011).

Second, especially concerning prosocial behavior, Persuasive Technology emphasizes the need for encouraging long-term usage and provides evidence of the positive influence of emotional attachment in this regard (Gegenbauer & Huang, 2012). According to Odom, Pierce, Stolterman, and Blevis (2009), there are four technology attributes that strengthen the attachment of the user toward the system and, in turn, promote longer use: (i) promotion of physical engagement, (ii) preservation of history, (iii) augmentation beyond its original intended use, and (iv) perceived durability.

Beyond the positive effect on prosocial behavior, reactance, and long-term usage, the emotional nature of the system also contributes to the trend of the car as a human-like co-driver. This trend emphasizes the relevance of non-functional quality aspects of technology, such as emotions, in order to keep up with the global market (Eyben et al., 2010; Gkouskos et al., 2015; Wiese et al., 2017).

6.3 Study 4: Online Survey

In order to get an initial evaluation of the idea of the DFA, an online survey was conducted. Similar to the ideas generated in the ideation workshops (*chapter V)*, the DFA was evaluated in terms of its likeability, usefulness, and innovativeness (Justel et al., 2007). Accordingly, the following research question (RQ3) was formulated: *how do people evaluate the likeability, usefulness, and innovativeness of the DFA?*

Moreover, to specify the DFA feedback algorithm, data on the severity of the nine relevant aggressive driving behaviors were required. This data is necessary to weigh the impact of the individual behaviors on the feedback, i.e., more severe violations should have a greater impact than milder ones. In general, it can be assumed that the behaviors differ in their severity (Özkan & Lajunen, 2005). The question is *how* bad (or good) people perceive the individual behaviors to be. This leads to the following research question (RQ4): *how do people assess the severity of different aggressive driving behaviors?*

Driven by business interests, the survey was originally designed to investigate the willingness to share personal data for the purpose of emotion recognition in the car. Questions addressing RQ3 and RQ4 were integrated as an additional part at the beginning of the survey.

6.3.1 Method

Questionnaire

The questionnaire was structured into three parts: (i) perceived severity of aggressive driving behaviors, (ii) initial evaluation of the DFA, and (iii) the willingness to share emotion-related data for the purpose of emotion recognition in the car (Appendix 4.1). The third part is not presented here.

The survey started with the query of the perceived severity of different aggressive driving behaviors. For this, participants assessed the severity of 15 aggressive driving behaviors (e.g., "not using turn signals when making a turn or changing lanes") and three prosocial driving behaviors (e.g., "using turn signals early enough when making a turn or changing lanes") on an 11-point scale ranging from "very negative" (-5) to "very positive" (5). The aggressive behaviors included the nine behaviors considered by the DFA, i.e., (i) tailgating, (ii) exceeding the speed limit,

(iii) not using the indicators before changing lanes, (iv) using the indicators shortly before changing lanes, (v) verbally insulting other road users, (vi) making insulting gestures toward other road users, (vii) flashing headlights at a slower vehicle, (viii) changing in one go from the right lane to the far left lane, and (ix) passing a single continuous center line. The additional negative behaviors, as well as prosocial behaviors, served as distractor and control items. Respondents were instructed as follows: "Please take a minute to think about which behavior patterns you consider particularly good or bad in drivers. Imagine you observe the following behaviors in another driver. How do you judge this behavior?" The third-person perspective was chosen to avoid a first-person effect, according to which it was assumed that respondents rate aggressive behaviors more severely when observed in others compared to when personally enacted (Golan & Day, 2008; Jensen & Hurley, 2005).

In the second part of the questionnaire, respondents were exposed to the DFA concept as well as four comparative ideas. The comparative ideas came up as part of the ideation workshops (*chapter V*) and were elaborated by their inventors independent of this thesis. Each system was introduced with a title and a short textual description but without any visualization:

- **Driving Feedback Avatar** (*Ger.* Emotionaler Fahrcoach): the driver is given feedback by the system about his or her driving behavior. The system identifies "friendly" driving behaviors (e.g., keeping a safe distance, letting other drivers merge) and "aggressive" driving behaviors (e.g., tailgating, exceeding the speed limit). The driver receives positive or negative feedback on every friendly or aggressive behavior. One example of negative feedback is that the vehicle would express its annoyance by displaying red interior lighting and a slight increase in the interior temperature.
- **Emotion-adaptive comfort functions** (*Ger.* Emotionsadaptive Komfortfunktionen): the system recognizes the driver's emotions and adjusts certain comfort functions (e.g., fragrance, massage, ambient lighting) according to the driver's mood and personal preferences.
- **Emotion-adaptive entertainment** (*Ger.* Emotionsadaptives Entertainment): the system recognizes the emotions of the driver and plays suitable music, audiobooks, or news in line with their mood and personal preferences.

- **Emotion-adaptive speed limiter** (*Ger.* Emotionsadaptiver Geschwindigkeitslimiter): studies have shown that angry drivers often drive too fast and exceed speed limits. The system is intended to help the driver to stay within existing speed limits even when strong emotions have been triggered. As soon as the system detects that the driver is angry, a resistance point in the gas pedal is activated, which makes it more difficult (requires more pressure) to push the gas pedal all the way to the floor. The resistance point adjusts to the current speed limit. Specifically, this means: when the driver pushes the gas pedal to the resistance point, the speed limit will not be exceeded. However, when the driver presses down hard on the gas pedal past the resistance point with noticeably more pressure, the speed limit will be exceeded.
- **Map of emotions** (*Ger.* Emotionslandkarte): the system recognizes the driver's emotions and combines this emotion data with the data of other drivers to create an "emotion map." This map illustrates areas (emotion areas) where drivers get particularly annoyed (e.g., on congested streets in the city center) or happy (e.g., pleasure driving on the open highway). Based on this information, the navigation system can, for example, suggest a particularly "enjoyable" route to the driver.

In a randomized order, respondents assessed each concept in terms of its likeability ("do not like it" - "like it"), usefulness ("not useful" - "useful"), and innovativeness ("not innovative" - "innovative") on a 5-point semantic differential (Justel et al., 2007). In addition, they were asked to provide suggestions for the improvement of each concept as an open answer.

The online survey was distributed in Germany using the online survey tool Questback that is linked to the Mercedes-Benz online panel. The panel database includes personal information about registered users, such as gender, age, or driving experience. The personal information was taken as a basis for the following sample description.

Sample

The dataset included the valid responses of 1047 respondents (189 female, 898 male). On average, they were 60.4 years old (SD = 12.9, range: 26-89; Figure 6.3.1). According to the Kolmogorov-Smirnoff test ($D(1047)$ = .06, p = .000), the data are not normally distributed, with non-symmetrical left-skewness of -.10 (SE = .08). In other words, the sample includes more people with a higher age. Of the respondents, 58.6 percent mainly drive a Mercedes-Benz car, followed by BMW (13.3 %), Audi (11.3 %), Volkswagen (7.4 %), and Skoda (2.6 %; others: 6.8 %). As internal information and market research indicate, there is a positive correlation between driver age and the class of the car, showing that high-class brands, such as Mercedes-Benz, BMW, or Audi, generally have older buyers. In the United States, for example, most people driving a Mercedes-Benz car are between 50 and 62 years old (Statistisches Bundesamt, 2020d). Thus, the sample is representative of the "classical" higher class car driver. On average, respondents drove 19,312 kilometers (*SD* = 13,933) in the last twelve months by car, which represents a high mileage compared to the German average that ranges between 10,000 and 15,000 kilometers (Statistisches Bundesamt, 2020b).

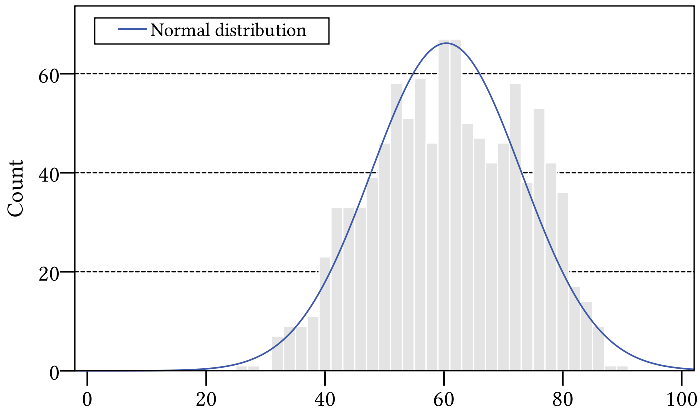


Figure 6.3.1. Age distribution of the online sample.

Data Preparation and Analysis

The numerical questionnaire data were analyzed using IBM SPSS Statistics. The free responses related to the DFA were processed using Microsoft Excel by extracting and summarizing (i) suggestions of improvement (e.g., "an acoustic signal is sufficient"), and (ii) evaluative attributes (e.g., "this information could *distract* the driver"). In total, 167 respondents gave a free answer.

To improve the validity of final dataset, (i) cases with an overall completion time slower than 40 percent of the average completion time of the entire sample and (ii) cases with inconsistent ratings of the control items (e.g., the aggressive driving behavior and its inverse formulation received the same rating) were excluded. These criteria applied to 15 cases, resulting in a final dataset of 1047 cases.

6.3.2 Results

Severity of Driving Behaviors

As shown in Table 6.3.1, the most negative assessed behavior was "tailgating a slower vehicle so closely that the headlights can no longer be seen in the rear-view mirror" (M = -4.30, SD = 1.23; scale: 5 "very negative" to 5 "very positive"), followed by "verbally insulting another driver" (M = -4.08, SD = 1.47), and "making an insulting gesture toward another driver" (M = -3.94, SD = 1.53).

Overall, aggressive lane change maneuvers (e.g., "not using turn signals when making a turn or changing lanes"; M = -3.44, SD = 1.67) and following behavior (e.g., "following a slower vehicle leaving no more than half of the recommended safe distance"; M = -3.46, SD = 1.62) were assessed as more negative than speeding violations (e.g., "exceeding the posted speed limit by up to 20 km/h on the highway"; M = -.36, SD = 2.21).

Noteworthy, the assumed aggressive behavior "exceeding the posted speed limit by up to 5 mph on the highway" (M = .78, SD = 1.88) was rated slightly positive. As expected, all assumed positive behaviors achieved positive ratings, i.e., "driving at or slightly below the posted speed limit" (M = .91, SD = 2.21), "keeping the recommended safe distance" (M = 2.17, SD = 2.46), and "using turn signals early enough when making a turn or changing lanes" (M = 3.60, SD = 1.85).

Table 6.3.1. Severity of prosocial and aggressive driving behaviors (*relevant for the conceptualization of the DFA).

Behavior	*M*	*SD*
Tailgating a slower vehicle so closely that the headlights can no longer be seen in the rear-view mirror*	-4.30	1.23
Verbally insulting another driver*	-4.08	1.47
Making an insulting gesture toward another driver*	-3.94	1.53
Cutting off another vehicle	-3.83	1.37
Passing from the right lane	-3.46	1.96
Following a slower vehicle leaving no more than half of the recommended safe distance*	-3.46	1.62
Not using turn signals when making a turn or changing lanes*	-3.44	1.67
Passing a single continuous center line to overtake*	-3.19	1.84
Not using turn signals until the last moment before making a turn or changing lanes*	-2.58	1.80
Exceeding the posted speed limit by more than 20 km/h on the highway*	-2.12	2.07
Changing in one go from the right lane to the far left lane on a road with at least three lanes*	-2.09	2.13
Flashing your headlights at a slower vehicle to signal it to move out of the way*	-2.08	2.46
Driving behind another vehicle falling just below the recommended safe distance*	-1.12	1.89
Exceeding the posted speed limit by up to 20 km/h on the highway*	-.36	2.12
Exceeding the posted speed limit by up to 5 km/h on the highway*	.78	1.88
Driving at or slightly below the posted speed limit	.91	2.21
Keeping the recommended safe distance	2.17	2.46
Using turn signals early enough when making a turn or changing lanes	3.60	1.85

N = 1047; scale: -5 “very negative” to 5 “very positive”

Evaluation of the Driving Feedback Avatar

Overall, the DFA was moderately rated by the respondents regarding its likability (M = 2.84, SD = 1.46; Table 6.3.2), usefulness (M = 2.90, SD = 1.32), and innovativeness (M = 3.58, SD = 1.31). All values were slightly lower or higher than the mean of the scale (M = 3.00), ranging from 1 (negative pole) to 5 (positive pole).

The DFA was compared with the four comparative systems (i.e., emotion-adaptive comfort function, emotion-adaptive entertainment, emotion-adaptive speed limiter, and map of emotions) through a repeated-measures ANOVA, including the five systems as a within-subjects factor and the three criteria as dependent variables (Field, 2013). Mauchly's test indicated that the assumption of sphericity was violated for each dependent variable (likability: $\chi^2(9) = 136.87$, $p = .000$; usefulness: $\chi^2(9) = 113.78$, $p = .000$; innovativeness: $\chi^2(9) = 91.85$, $p = .000$). Correcting degrees of freedom using Greenhouse-Geisser estimates of sphericity (likability: $\varepsilon = .95$; usefulness: $\varepsilon = .95$; innovativeness: $\varepsilon = .96$), there was a significant difference regarding the likability ($F(3.78, 3952.57) = 62.95$, $p = .000$, $\eta = .13$), usefulness ($F(3.82, 3990.16) = 79.95$, $p = .000$; $\eta = .14$), and innovativeness ($F(3.85, 4022.82) = 39.07$, $p = .000$; $\eta = .10$) within the systems. According to Cohen (1988), however, these effects are only small (Bakeman, 2005).

Considering the Bonferroni-adjusted pairwise comparisons of the DFA with the comparative systems (Table 6.3.2), it shows that the DFA was rated significantly less likable, useful, and innovative, relative to the comparative systems. Only the post-hoc test between the DFA and the emotion-adaptive entertainment in terms of innovativeness did not reach statistical significance.

Table 6.3.2. Post-hoc comparisons of the DFA with the comparative systems (Bonferroni-adjusted).

	Likability			**Usefulness**			**Innovativeness**		
System	*M*	*SD*	*p*	*M*	*SD*	*p*	*M*	*SD*	*p*
Driving Feedback Avatar	2.84	1.45	-	2.90	1.32	-	3.58	1.31	-
Emotion-adaptive comfort function	3.45	1.31	.000	3.29	1.23	.000	3.78	1.16	.000
Emotion-adaptive entertainment	3.28	1.38	.000	3.18	1.27	.000	3.65	1.20	.538
Emotion-adaptive speed limiter	3.51	1.36	.000	3.66	1.21	.000	3.97	1.11	.000
Map of emotions	3.40	1.41	.000	3.35	1.31	.000	3.87	1.21	.000

N = 1047; scale: 1 positive pole to 5 negative pole

Of the respondents, 167 provided an additional free-response to the evaluation of the DFA. The most outstanding insights are reported in the following. Thirty respondents stated that they would feel patronized by the system (e.g., "I definitely do not want to receive comments about my driving behavior from my vehicle" or "This is an ideology for a compliant society without individuality"). Twenty-one people were worried that the system might promote aggression (e.g., "I think the vehicle's anger actually encourages aggressive driving"). Eight individuals expressed concerns regarding driver distraction (e.g., "Too much technology creates a risk of distraction"). In total, 66 respondents provided a suggestion for improvement. Most of their ideas referred to the primary use of rewards instead of punishment (e.g., "The system should rather praise the driver for positive driving, for example, through optical points or pictures") and the implementation of auditory feedback (e.g., "Use beeps with different volume").

6.3.3 Conclusion and Discussion

The online study provides a first indication of *how people evaluate the likeability, usefulness, and innovativeness of the DFA* (RQ3) and *how they assess the severity of different aggressive driving behavior* (RQ4). In total, 1047 German respondents provided answers to these questions. The DFA reached average scores for all evaluation criteria, i.e., the system is moderately likeable, useful, and innovative. However, compared to selected competitor systems (i.e., emotion-adaptive comfort function, emotion-adaptive entertainment, emotion-adaptive speed limiter, and map of emotions), the DFA performed worse on all three dimensions. This might be explained by the fact that respondents associated the DFA with the feeling of being patronized, reactance, and driver distraction. In order to improve the concept, they recommended focusing on positive feedback for good behavior instead of negative feedback for aggressive behavior and the use of auditory feedback. Concerning the severity of the different aggressive driving behaviors, the most negative behavior was strong tailgating. Moreover, respondents also rated aggressive behaviors that cause no physical damage as extremely negative, such as verbal insults and insulting gestures. Following, these behaviors should have a greater impact on the feedback given by the DFA. Also noteworthy, slightly exceeding the speed limit is rated positively. This implies that minor traffic violations—in some cases—are generally accepted and should not be punished by the DFA.

From a methodological perspective, the composition of the sample has to be seen in a critical way because it mainly consisted of male respondents, older respondents, respondents with significant driving experience, and respondents driving a higher-class car, such as a Mercedes-Benz, BMW, or Audi. Due to their higher age, it could be assumed that the respondents are less open to innovative technologies (Franke, Attig, & Wessel, 2019). Due to their high level of driving experience, respondents could be seen as “driving experts,” who are unwilling to accept feedback on their driving style from a system (Ehrenbrink & Prezenski, 2017). These reasons could have negatively influenced the evaluation of the DFA and, moreover, reflect the opinion of a specific group of people. With regard to the assessment of the severity of the different driving behaviors, the operationalization using the labels “positive” and “negative” should be discussed. There is a risk that this scale was too general so that it might be unclear how the respondents interpreted the labels. For example, some respondents may have assessed the behaviors based on the perceived risk of a traffic accident, while others focused on the extent to which the behavior is seen as a personal attack.

What differentiates the DFA from comparative solutions is its capability to recognize and express emotions in a human-like way. In doing so, the system incorporates a feature that is relatively new. As known from the literature, unfamiliarity is a salient factor that is associated with risk and uncertainty and, therefore, plays a significant role in the evaluation of technology innovations (Jalonen, 2012; Wells, Campbell, Valacich, & Featherman, 2010). Making an argument for the pursuit of the idea of the DFA, it can be assumed that the moderate evaluation of the system is the consequence of the perceived risk and uncertainty associated with its emotionality and that this characteristic could even emerge as a success factor if people get used to it. What can also be learned from this study is that there are certain factors that have to be taken into account in a more detailed evaluation of the DFA, such as the issue of driver distraction, perceived paternalism, and reactance. Moreover, the present investigation obtained data relevant for the further development of the feedback algorithm of the DFA, which is described in the following chapter.

6.4 Next Step: Prototyping

In conclusion, this chapter has elaborated upon a visual in-car interface that is supposed to mitigate aggressive driving, the DFA. The DFA provides the driver with feedback on his driving performance with a special focus on aggressive driving on the highway. The system considers behaviors such as tailgating, speeding, or insulting gestures. What is unique about the system is that the feedback is represented by the emotional state of an abstract avatar. In the absence of aggression, the avatar is relaxed (positive feedback). If the driver drives aggressively, the avatar becomes angry (negative feedback). These emotional states are modeled by animating the avatar in terms of color and dynamics, i.e., the redder (or blue) the avatar appears and the faster it moves, the angrier (or relaxed) it is. While the emotional state changes by degrees and thus can be seen as summative feedback over the elapsed driving time, an additional visual alert is given instantly after an aggressive action is shown.

The feedback provided by the DFA is intended to raise the user's awareness of aggressive driving, which is a main driver for behavior change. In addition, the system's persuasiveness is supposed to derive from its capacity to express emotions and its gamified nature. Even if it was theoretically worked out that these characteristics might give persuasive power to the DFA, this assumption has to be verified empirically. Thus, the next steps are to implement the system concept in a prototype and evaluate it under experimental conditions.

VII. CHAPTER

EVALUATION OF THE DRIVING FEEDBACK AVATAR

7.1 Background

This chapter constitutes the last step of the HCD process, in which the produced system solution, the DFA, is evaluated. The question is whether the system can change aggressive driving effectively and how it is perceived by potential users (Maguire, 2001).

To examine the effectiveness of behavior change support systems, the target behavior has to be measured before and after the intervention in question. In the case of driving behavior, there are two major methods to collect data: simulator studies and driving studies in real traffic. Simulator studies benefit, most of all, from their controllability, reproducibility, and standardization. Moreover, they make it possible to study dangerous scenarios without physical risk, caused by, for instance, driver distraction, drowsiness, or stress. However, skills learned in a simulation cannot be transferred to the real world one-to-one. Thus, real-world driving studies are the preferential approach when it comes to the investigation of behavioral changes. They show their advantages in their physical, perceptual, and behavioral fidelity (de Winter, van Leeuwen, & Happee, 2012). Against this background, this chapter presents a real-world driving study that answers the question on the effectiveness of the DFA (RQ5): *does the DFA mitigate aggressive driving effectively?*

In contrast to behavioral outcomes, a user's perception of a system is a subjective and multifaceted construct. With regard to the DFA, some perception-related factors were uncovered in the online survey (*6.3 Study 4: Online Survey*), including the issue of driver distraction caused by the system, reactance toward the system, and the feeling of being patronized by the system. Driver distraction occurs when a stimulus, inside or outside the car, shifts the attention away from the primary driving task, including all activities related to the lateral and longitudinal control of the car and the alertness to potential hazards in the driving situation (Horberry et al., 2006). Psychological reactance is an unpleasant motivational state that an individual enters when he perceives a threat to his freedom and that may lead to aggressive responses (Brehm, 1966). In the case of the DFA, it must be examined whether the feedback itself was perceived as threatening. Finally, technology paternalism describes the imposition of solutions to people's assumed problems without their consent (Spiekermann & Pallas, 2006). Persuasive systems attempt to direct the user toward a specific behavior. If this attempt conflicts with the free and autonomous choice of the individual, the risk of feeling patronized is high (Spahn, 2012). As shown in section *6.2.4 Theoretical Foundations*, other relevant perceptional factors of the DFA are the awareness of aggressive driving raised by the system, the gaming experience when interacting with the system, and the emotional attachment toward the system triggered by its emotional design. These variables are supposed to influence the persuasive power of the DFA. In conclusion, there are several perceptional factors potentially related to the DFA so the question is (RQ6): *how do people perceive the DFA?*

7.2 Study 5: Experimental Driving Study

To investigate the effectiveness (RQ5) and perception (RQ6) of the DFA, the system was implemented in a prototype. In a within-subjects design, the prototype was used to examine whether the presence of the DFA has an effect on aggressive driving, manifested in the following hypothesis:

H1: *the presence of the DFA reduces the frequency of aggressive driving behaviors, in particular, those that are fed back by the system.*

Moreover, it was theoretically assumed that the persuasiveness of the DFA depends on (i) the driver's awareness of aggressive driving raised by the system, (ii) the driver's gaming experience when interacting with the system, and (iii) the driver's emotional attachment to the system.

This dependency constitutes a working model, according to which the aforementioned factors are seen as moderators of the relationship between the presence of the DFA and its effect on aggressive driving. In order to test the fulfillment of these prerequisites, the following hypotheses are examined:

H2a: *the DFA raises an awareness of aggressive driving, in particular, of the behaviors that are fed back by the system.*

H2b: *the DFA increases the gaming experience while driving.*

H2c: *people feel emotionally attached to the DFA.*

7.2.1 Method

Wizard-of-Oz Prototype

The DFA was implemented in a Wizard-of-Oz (WoZ) prototype (Figure 7.2.1). A WoZ prototype is a prototypical system that is manually handled by a human operator to simulate the functionality of a system that does not yet exist. WoZ methods have a long tradition in driver-vehicle-interaction research to test systems that require considerable hardware and software architecture. Often, prototypical in-car interfaces are implemented in test vehicles and are operated by an experimenter who is sitting in the back seat and using a control panel (Martelaro & Ju, 2017). The prototype of the DFA was built into a Mercedes-Benz E-class that was equipped with a CAN bus logger that recorded the internal vehicle communication (e.g., driving speed, torque, or GPS position). The prototype consisted of four components: (i) a tablet screen displaying the avatar in the driver's area (*avatar tablet*), (ii) a tablet with a graphical interface so that an experimenter sitting behind the driver's seat was able to operate the wizard (*annotation tablet*), (iii) a tablet that was connected to the CAN bus logger and visualized relevant vehicle data for the backseat experimenter (*monitoring tablet*), and (iv) a *laptop* running the algorithm that determined the feedback. The four components are described in detail below.

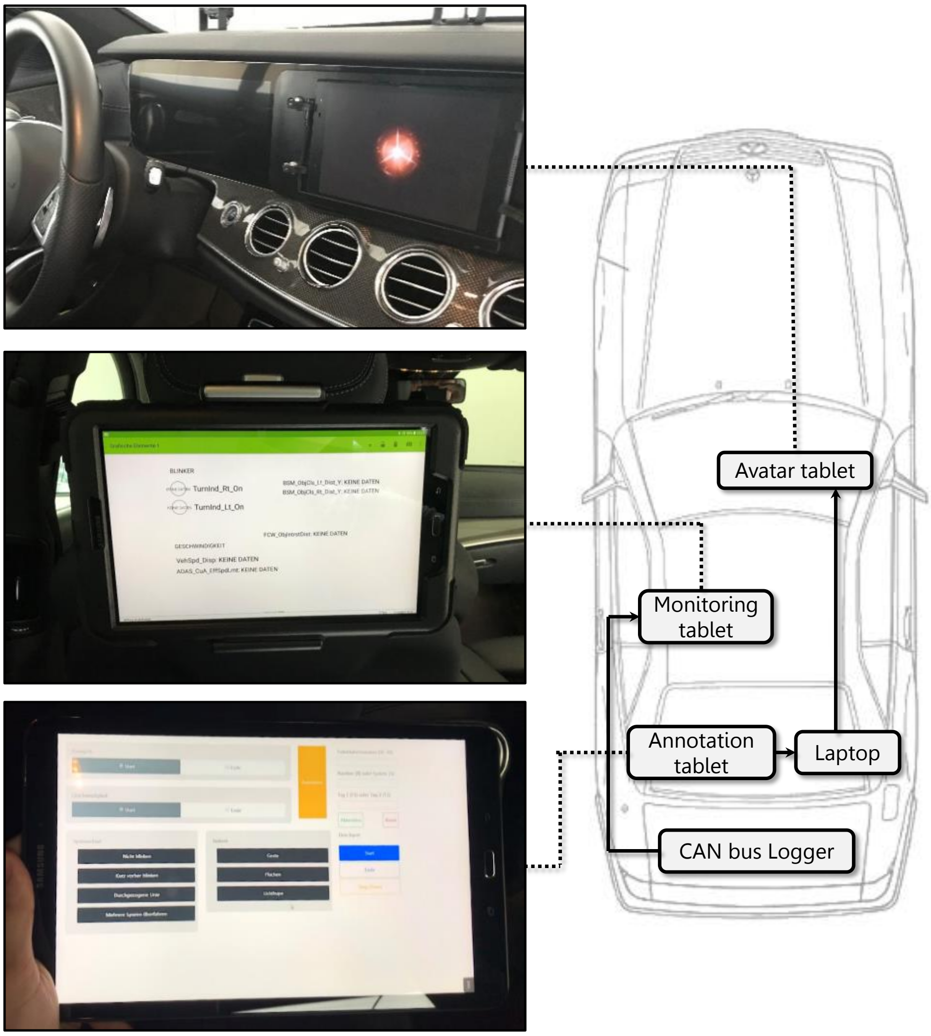


Figure 7.2.1. Wizard-of-Oz setup of the DFA.

- **Avatar tablet:** the avatar tablet was fixed on top of the center console display. This position is clearly visible from the driver's seat, and the center console display does not contain information relevant for the primary driving task (e.g., driving speed or warnings) that could be hidden by the tablet.
- **Annotation tablet:** the experimenter was sitting behind the driver's seat and manually annotated the following nine behaviors using the annotation tablet held in hand:

(1) Tailgating
(2) Exceeding the speed limit
(3) Not using the indicators before changing lanes
(4) Using the indicators shortly before changing lanes
(5) Verbally insulting other road users
(6) Making insulting gestures toward other road users
(7) Flashing headlights at a slower vehicle
(8) Changing in one go from the right lane to the far left lane (on a road with at least three lanes)
(9) Passing a single continuous center line

Via the graphical user interface of the annotation tablet (Figure 7.2.2), discrete behaviors (i.e., use of indicators, verbal insults, insulting gestures, flashing headlights, lane changes) were annotated by pressing a button. Continuous behaviors (i.e., tailgating and speeding) were opted in once started and opted out at the end.

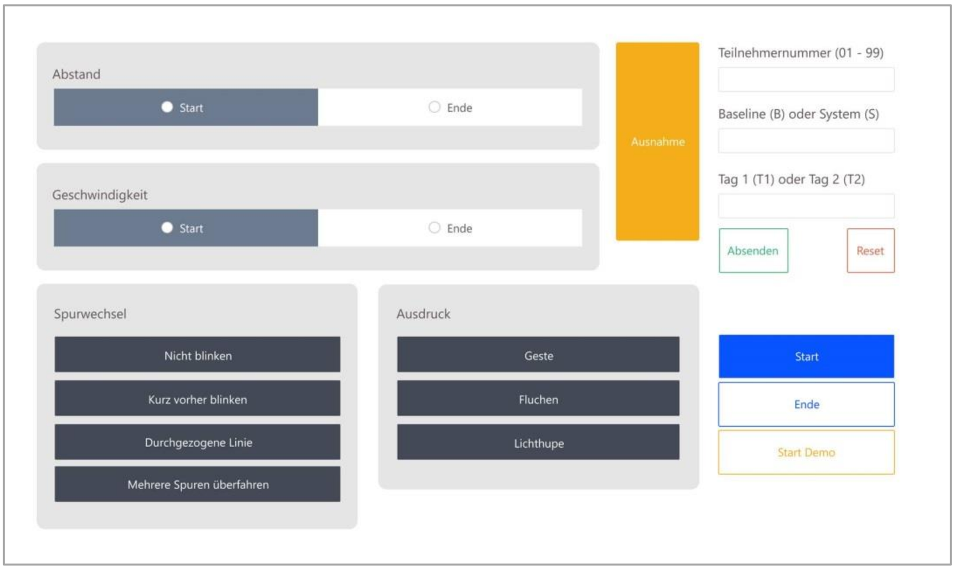


Figure 7.2.2. Graphical user interface of the annotation tablet.

- **Monitoring tablet:** to support the experimenter in the annotation task, the monitoring tablet visualized data related to the relevant behaviors, including the distance to the vehicle ahead in meters, the current driving speed in km/h, the value of the current speed limit, and the activation of the indicators as well as the high beams. The tablet was fixed at the back of the driver's seat so that the annotator was able to see the information at any time.
- **Laptop and algorithm:** the annotation tablet and the avatar tablet were connected to the laptop running the feedback algorithm. The laptop was fixed to the backseat next to the experimenter so that it would not move in the event of a crash. Based on the type and number of annotated behaviors, the algorithm calculated a score by multiplying the frequency of the behaviors with their severity and summing up the product of this multiplication over the driving time. The severity values were adapted from the online study (*6.3 Study 4: Online Survey*). In the case of discrete behavior, i.e., a single action at a time, the score was adjusted by the severity value once the behavior was annotated. In the case of continuous behavior, i.e., a sequence of actions over a period of time, the severity value was subtracted every 10 seconds as long as the behavior was opted in. For example, if a driver exceeded the speed limit for 5 seconds, 1.24 points were subtracted from the current score. Likewise, he lost 1.24 points if he was speeding for 10 seconds. If he speeded for 11 seconds, however, the score was reduced by 2.48 points, i.e., twice the number of the severity value. In addition, every second a positive factor, which was significantly lower than the lowest severity value, was added to reward the absence of aggression. The current score was constantly mapped to the nine emotional states of the avatar. Once the score exceeded the upper (or lower) threshold defined for a state, the avatar changed to the next (or previous) state. The avatar's emotional states were saved as individual mp4 animations. To ensure a smooth transition between the states, the animations were faded in and out. The algorithm not only controlled the avatar's emotional state but also activated the instant feedback, i.e., every time the annotator made an entry, the background of the avatar tablet flashed twice in orange. The WoZ application automatically created a CSV file, in which the annotation tags were saved. The tags were logged with a frequency of 1 Hz, i.e., every second an entry was made.

Procedure

The driving study was conducted on a public highway in the area of Stuttgart (Germany), including two test drives with the test vehicle that was driven by the participants (Figure 7.2.3). The test drives were each randomly assigned to one of two conditions: test drive *with* the WoZ prototype of the DFA installed in the car (system condition) and test drive *without* the prototype (baseline condition). There was one week between the trials, with both trials taking place on the same weekday and time of day to keep environmental conditions constant (e.g., rush hour). There and back, the test route was a 50-kilometer long, including sections with different speed limits, a section with a continuous centerline, and two- and three-lane roads (Appendix 5.1). The on-board navigation system guided participants.

In both conditions, one of four experimenters (2 female, 2 male) accompanied the participant, with each participant completing both trials with the same person. In both conditions, the experimenter operated the DFA following an annotation guide (Appendix 5.3). However, in the baseline condition, the avatar tablet was not installed. It was assumed that participants would tend to drive more conservatively in the study than under normal conditions, making it hard to observe real aggressive driving. Known from other investigations, the presentation of the research objective to the subjects can cause them to behave in a way that confirms this intention (Nichols & Maner, 2008). Thus, the participants were asked to drive as naturally as possible. Moreover, the presence of the experimenter was framed in a cover story (original German version in Appendix 5.2):

> *We are developing an assistance system to support driving on the highway. Because of this, we are interested in the most common driving maneuvers, including lane changes, overtaking maneuvers, and so on. Thus, for today, we want to observe your natural driving behavior. Observing means that this vehicle is equipped with a computer that records your driving. Your job for today is to drive as usual as possible. We want to know: how close do you drive to other vehicles? How fast do you drive? When do you use the indicators? How do you change lanes or overtake? As we are interested in your natural driving behavior, you are not allowed to use the driving assistance systems, such as adaptive cruise control or lane departure warning. I will sit behind you and accompany*

> *the drive. However, please do not to talk to me. I am just here to monitor the computer and check that everything works well. Just pretend I am not here.*

The first part of the instruction was the same under both conditions. In the system condition, participants were additionally familiarized with the DFA by showing them a video demonstration in the avatar tablet (original German version in Appendix 5.2):

> *What you can see here is the prototype of an assistance system that responds to your driving behavior [...]. The system recognizes, for example, your driving speed, distance to other vehicles, use of indicators, lane change behavior, gestures, and verbal expressions. Depending on these behaviors, the animation changes. If you drive appropriately, the avatar will gradually turn blue, which indicates a positive emotional state, meaning 'my driving style is good for my vehicle and others.' If you drive inappropriately, the avatar turns red, which represents a negative emotional state, conveying the message 'my driving style is bad for my vehicle and others.'*

Before the first drive, participants were introduced to the test vehicle and the test route on a map. In addition, they completed a color vision test to ensure that they were able to correctly interpret the color of the different emotional states of the avatar. All participants passed the test. After each drive, they filled in a questionnaire to assess their driving experience. In the system condition, they were also asked about their perception of the system in the questionnaire as well as in a short interview directly after the drive.

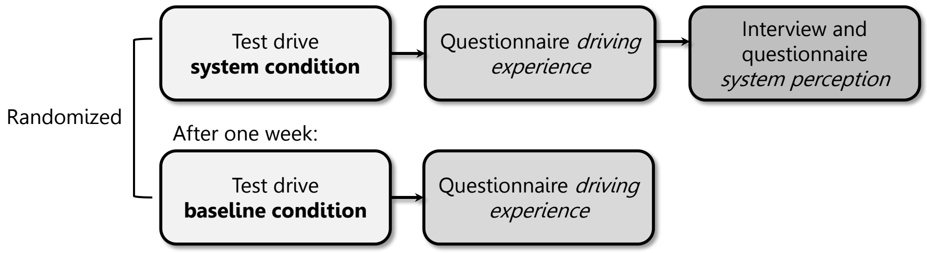


Figure 7.2.3. Procedure of the experimental driving study.

Driving Experience Measures

In order to address H2b, the questionnaire queried (i) participants' gaming experience while driving (Appendix 5.5). In addition, (ii) their naturalness of driving and (iii) their driver distraction were measured as confounding variables. The variables were addressed by the following measures and in the following order:

- The **naturalness of driving** was operationalized by (i) the familiarity with the handling of the test vehicle (scale: 1 "very unfamiliar" to 7 "very familiar"), and (ii) the deviation from normal driving with a focus on driving speed, distance to preceding vehicles, use of indicators, timing of indicating, and verbal insult (scale example: 1 "I drove faster than usual" to 4 "I drove as usual" to 7 "I drove slower than usual"). Here, higher values indicate a more conservative behavior during the study. Only after the second trial (independent of the experimental condition), the questionnaire additionally included a self-assessment of the participants' (iii) general tendency for aggressive driving on a 5-point scale (1 "not aggressive at all," 2 "slightly aggressive," 3 "moderately aggressive," 4 "aggressive," 5 "very aggressive").

- **Driver distraction** was measured through the *Driving Activity Load Index* that determines the overall mental workload a driver perceives while driving, including the use of an in-vehicle system or not (Pauzie, 2009). The index reaches high values for complex driving conditions. By providing a 22-level slider scale with the poles 1 "low" and 22 "high," the tool queries the following dimensions: effort of attention, visual demand, auditory demand, temporal demand, interference, and situational stress

- The participants' **gaming experience** was measured using the *In-game Game Experience Questionnaire* that was originally aimed at probing a player's feelings while playing a game (Poels et al., 2013). The questionnaire assesses the construct on seven components, including immersion, flow, competence, positive and negative affect, tension, and challenge. Transferred to the present context, participants indicated how they felt while driving, indicating their agreement to 13 feeling-related statements (e.g., "I felt skillful") on a 5-point scale (1 "not at all," 2 "slightly," 3 "moderately," 4 "fairly," 5 "extremely"). One item of the original questionnaire was excluded because it was not transferable to the context of driving ("I was interested in the game's story"). Inverse formulated items were transcoded in the later analysis so that higher values indicate a better gaming experience.

System Perception Measures

Considering the perception of the DFA, the dependent variables are (i) the participants' emotional attachment to the DFA (H2c) and (ii) their awareness of aggressive driving (H2a). In addition, (iii) the user experience of the DFA as a "standard" quality criteria and (iv) the perceived paternalism of the system as a confounding variable were captured. While participant awareness was addressed in the interview (Appendix 5.4), the other variables were captured via questionnaire (Appendix 5.5). The variables were addressed in the order described below.

- In the interviews on the **awareness of aggressive driving**, participants were explicitly asked whether they were paying attention to the avatar or not and to list the driving behaviors supposedly recognized by the system. Moreover, they were requested to describe the distracting aspects of the system.
- In the questionnaire, the short version of the *User Experience Questionnaire* was used to measure the **user experience** associated with the DFA (Alberola, Brau, & Walter, 2017; Laugwitz, Held, & Schrepp, 2008). The questionnaire consists of several 7-point semantic differentials asking for the system's global attractiveness (4 items, e.g., "good—bad"), pragmatic quality (3 items, e.g., "not understandable—understandable"), and hedonic quality (4 items, e.g., "creative—dull"). Pragmatic quality addresses a product's utility and usability, while hedonic quality refers to the fulfillment of the human needs for autonomy, competency, stimulation, relatedness, and popularity when interacting with the technology (Hassenzahl, Burmester, & Koller, 2003). Inverse differentials were transcoded for the analysis, thus, the lower the mean value of a sub-scale, the better the user experience.
- The participants' **emotional attachment** to the DFA was measured by adapting the *Mother-to-Infant Bonding Scale* (MIBS), which was designed to assess a mother's feelings toward her newborn from day one postpartum by offering single attributes of possible emotions toward her new child (Taylor, Atkins, Kumar, Adams, & Glover, 2005). The MIBS was used because no validated instrument exists that captures a user's attachment to technology

on an emotional level. The MIBS is based on three positive attributes (e.g., “protective”) and five negative attributes (e.g., “aggressive”) that are assessed on a 4-point scale with the options 0 “not at all,” 1 “a little,” 2 “a lot,” and 3 “very much.” For the present study, the attributes were formulated as statements (e.g., “The avatar makes me aggressive”) and the option “moderately” was added to offer a neutral choice, resulting in the following scale: 0 “not at all,” 1 “a little,” 2 “moderately,” 3 “a lot,” and 4 “very much.” The MIBS score is the sum of all ratings, whereby negative attributes are transcoded. Thus, a maximum score of 32 can be reached, which indicates the highest level of emotional attachment.

- Finally, participants indicated their **feeling of being patronized** by the system using a 7-point scale (1 “I did not feel patronized at all” to 7 “I felt very much patronized”).

All questionnaire items were implemented into the online questionnaire tool Questback and administered in German, using a validated translation of their original formulation. All items were coded as semi-mandatory options to prevent missing values, i.e., participants were informed of their missing answer but could continue without entering an answer. In addition to the mentioned variables, participant’s personal background information (e.g., age, gender, or driving experience) was collected at the beginning of the very first questionnaire session.

Sample

Participants were recruited via the Mercedes-Benz user study pool (Mercedes-Benz, 2019). To promote natural driving in the study, the focus was on participants who (i) regularly drive a car similar to the test vehicle in terms of performance and features, (ii) live in the area around the test route, and (iii) have a driving experience of around 10,000 kilometers per year. Participants received an expense allowance of 80 Euro.

In total, 32 participants (15 female, 16 male, 1 not specified) completed both trials (one participant missed the second appointment). On average, they were 46.3 years old (SD = 13.9, min: 21, max: 67). Of the participants, 19.4 percent drove less than 10,000 kilometers in the last year by car, 54.8 percent drove between 10,000 and 30,000 kilometers, and 25.8 percent drove more than 30,000 kilometers. Eleven regularly drove a Mercedes-Benz E-class or C-class. Other cars driven included, for example, Opel Insignia, Volkswagen Passat, or Audi A5.

Participants felt very familiar with the test vehicle when driving with the prototype of the DFA ($M = 6.44$, $SD = .80$) and when driving without it ($M = 5.91$, $SD = 1.59$). They felt even more familiar with the vehicle when driving with the system ($t(31) = 2.32$, $p = .027$). Moreover, they indicated driving almost as usual in terms of driving speed (system: $M = 4.16$, $SD = .68$; baseline: $M = 4.00$, $SD = .67$), distance to preceding vehicles (system: $M = 4.00$, $SD = .36$; baseline: $M = 4.03$, $SD = .31$), use of indicators (system: $M = 4.06$, $SD = .25$; baseline: $M = 4.03$, $SD = .18$), and timing of indicating (system: $M = 4.03$, $SD = .47$; baseline: $M = 4.03$, $SD = .31$). Here, a rating of 4 indicates the highest level of usualness. Ratings above 4 represent a more conservative behavior in the study. However, participants stated that they made significantly less verbal insults in both test drives, relative to normal (system: $M = 4.69$, $SD = 1.18$, $t(31) = 3.31$, $p = .002$; baseline: $M = 4.97$, $SD = 1.28$, $t(31) = 4.27$, $p = .000$). In general, participants assessed themselves as "slightly aggressive" drivers ($M = 2.19$, $SD = .91$), with no one being "very aggressive."

Regarding the issue of driver distraction, a paired sample t-test shows that the system had no negative influence as there is no significant difference between the system condition ($M = 4.27$, $SD = 2.69$) and the baseline condition ($M = 4.45$, $SD = 2.74$; $t(27) = -.46$, $p = .650$). Relative to the scale maximum of 22, driver distraction is generally low, assuming that the driving conditions (e.g., presence of the prototype or the experimenter, test route) were not too complex.

Data Preparation and Analysis

Three types of data were collected in the study: (i) the interview and questionnaire data, (ii) the driving data recorded by the CAN bus logger, and (iii) the manually annotated behavior tags. Independent of the data type, the experimental conditions were compared using the complete case method, i.e., only participants with complete data for both trials were considered in the analysis (Karahalios, Baglietto, Carlin, English, & Simpson, 2012). In the case of the interview and questionnaire data, the datasets of all 32 participants were considered. In the case of the behavioral data, however, the datasets of three participants were excluded from the analysis, resulting in 29 valid datasets. For one participant, no data was logged in the first trial due to technical problems. For the other participants, the route of at least one trial was changed due to traffic obstructions so that both trials were not comparable.

The questionnaire data were analyzed using IBM SPSS Statistics. The interview notes were transcribed and summarized in Microsoft Excel.

From the CAN bus data, signals related to the annotated aggressive driving behaviors were extracted (e.g., driving speed, distance to objects ahead, or activation of indicator). For the behaviors verbal insult and insulting gestures, no CAN bus data were available. In these cases, information was extracted from the manually annotated data (see next paragraph). The preparation of the CAN bus data was done in three steps. First, the relevant signals were preprocessed using the programming tool Octave. As all signals were logged with different frequencies, they were averaged to 1 Hz (i.e., the file contained one value per second for all signals). Moreover, cases with a driving speed of less than 70 km/h were excluded to systematically filter out congestion phases. Second, from the preprocessed data, cases in which a relevant aggressive action occurred were determined using IBM SPSS Statistics. The relevant cases were determined by specifying signal values, as summarized in Table 7.2.1. For the behavior "exceeding the speed limit," for instance, cases were classified as valid if the speed limit signal had the value 100 and the driving speed signal had the value 117. In general, exceedances of less than 10 km/h were not considered, since the online survey (*6.3 Study 4: Online Survey*) revealed that milder speeding violations are considered legitimate. Tailgating was specified as following the vehicle ahead with a distance of less than half of the recommended safe distance (i.e., "half of the speed indicator"). Milder distance violations are not (or only marginally) penalized according to the German traffic regulations so that they were also not considered. Third, to standardize the behavioral data, the duration of the continuous behaviors in minutes per hour and the frequency of the discrete behaviors per hour were calculated.

The annotated data were available with a frequency of 1 Hz. Analogous to the CAN bus data, the duration of the continuous behaviors in minutes per hour, and the frequency of the discrete behaviors per hour were determined. Then, the verbal insult tags and insulting gestures tags were merged into the SPSS file of the preprocessed CAN bus data.

Table 7.2.1. Analyzed driving data and their specifications.

Behavior	Specification	Duration
Exceeding the speed limit	Exceeding existing speed limit (100 km/h or 120 km/h) by a minimum of 10 km/h	continuous
Tailgating	Following the vehicle ahead with a distance of less than half of the recommended safe distance (“half of the speed indicator”)	continuous
Not using the indicators before changing lanes	Indicators (left or right) are not activated in an observed time frame of 10 seconds before the lane change	discrete
Using the indicators shortly before changing lanes	Indicators (left or right) are activated at least 1 second before the lane change	discrete
Flashing headlights at a slower vehicle	As long as the high-beam is activated (night drives were not possible)	discrete
Changing in one go from the right lane to the far left lane	Starting a second lane change directly after a first lane change was completed	discrete
Passing a single continuous center line	Changing lanes when a single continuous center line is detected	discrete
Verbally insulting other road users	*Manually annotated behavior tag*	discrete
Making insulting gestures toward other road users	*Manually annotated behavior tag*	discrete

Quality of Annotation

To check the quality of the annotation, the manually annotated data were compared with the corresponding CAN bus data through an independent sample t-test (Field, 2013). Exemplary, the behaviors tailgating and speeding are analyzed. In the baseline condition, the experimenter annotated about as many tailgating violations ($M = 7.90$, $SD = 7.62$) and speeding violations ($M = 6.95$, $SD = 9.23$) as automatically recorded by the CAN bus logger (tailgating: $M = 9.41$, $SD = 7.31$, $t(56) = .77$, $p = .445$, $d = .20$; speeding: $M = 11.38$, $SD = 7.85$, $t(56) = 1.97$, $p = .054$, $d = .50$), which makes an argument for the accuracy of the manually annotated data. In the system condition, however, there was a significant difference for both behaviors, i.e., the experimenter annotated significantly less tailgating events ($M = 6.64$, $SD = 6.21$) and significantly less speeding events ($M = 6.49$, $SD = 6.62$) than actually occurred (tailgating: $M = 12.15$, $SD = 10.52$, $t(45.42) = 2.43$, $p = .019$; speeding: $M = 13.50$, $SD = 8.10$, $t(56) = 3.62$, $p = .001$). According to Cohen (1988), the effects are medium (tailgating: $d = .61$) to strong (speeding: *d* = .86). This means that the participants did not always receive feedback from the DFA on aggressive driving behavior. Even if the incongruence between the behavior shown and the feedback provided could have reduced the effectiveness of the system, the accuracy of the CAN bus data was not affected by this.

7.2.2 Results

Effectiveness

On average, a drive took 25 minutes (*SD* = 4) in the baseline condition and 26 minutes (*SD* = 2) in the system condition, including only sections with a driving speed of at least 70 km/h. The behavior “passing a single continuous center line” was never shown. The relative frequencies of the remaining eight behaviors were compared within both conditions using paired sample t-tests under the necessary prerequisites to address hypothesis H1: *the presence of the DFA reduces the frequency of aggressive driving behaviors, in particular, those that are fed back by the system.* Since there was a presumed direction of the effect, the tests were one-tailed (Field, 2013).

- **Speeding:** in general, participants drove faster in the system condition (km/h: *M* = 118.93, *SD* = 6.15) than in the baseline condition (km/h: *M* = 117.01, *SD* = 6.18). Since this result is in the opposite direction to what was expected, the one-tailed test is not interpreted. The two-tailed test indicates that this difference is not significant (*t(28)* = -1.83, *p* = .077, two-tailed, *d* = .34). Furthermore, more speeding violations could be observed when the DFA was present, i.e., participants exceeded the speed limit 13.50 minutes per hour (*SD* = 8.10) in the system condition and only 11.38 minutes (*SD* = 7.85) in the baseline condition (Figure 7.2.4). Again, the descriptive statistics are in the wrong direction so H1 is rejected in terms of speeding. The two-tailed test reveals that the occurrence of speeding violations do not differ significantly between the conditions (*t(28)* = -1.33, *p* = .196, two-tailed, *d* = .25).
- **Tailgating:** considering the general distance to the vehicle ahead, participants followed slightly closer when driving with the DFA (meter: *M* = 64.65, *SD* = 17.14) than when driving without it (meter: *M* = 66.29, *SD* = 16.40). Since a reverse effect was assumed, the results of the one-tailed test are ignored. The two-tailed test shows that the increase of the following distance in the system condition

is not significant (*t(28)* = .77, *p* = .449, two-tailed, *d* = .14). Tailgating was defined as less than half of the recommended safe distance. Accordingly, participants tailgated 12.15 minutes per hour of driving (*SD* = 10.52) when driving with the system and only 9.41 minutes (*SD* = 7.31) when driving without it (Figure 7.2.4). Also, this result contradicts H1 so that the one-tailed test is not interpreted. The two-tailed test reveals that the difference is not significant (*t(28)* = -1.82, *p* = .080, two-tailed, *d* = .34).

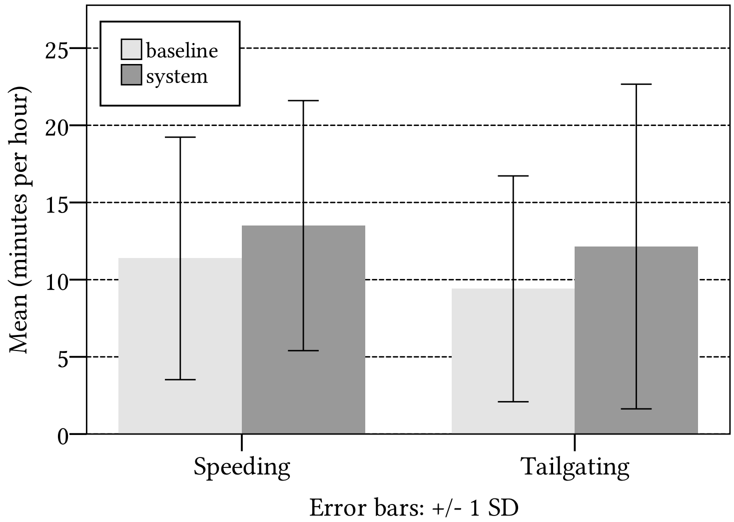


Figure 7.2.4. Continuous aggressive driving behaviors speeding and tailgating.

- **Use of indicators**: regarding the use of indicators, a distinction was made between whether they were not activated at all when changing lanes or only shortly before the maneuver, specified as one second (Figure 7.2.5). The no indicator event occurred at an average of 1.49 times per hour (*SD* = 1.54) in the baseline condition and only .97 times per hour (*SD* = 1.33) in the system condition (*t(28)* = 1.62, *p* = .058, one-tailed, *d* = .44). Likewise, the short indicator event was observed 29.47 times per hour (*SD* = 25.99) in the baseline condition and only 26.36 times per hour (*SD* = 20.35) in the system condition (*t(28)* = .78, *p* = .222, one-tailed, *d* = .14). Although both comparisons do not reach statistical significance, they demonstrate a general decrease in aggression when the DFA was present and, thus, weakly support H1.

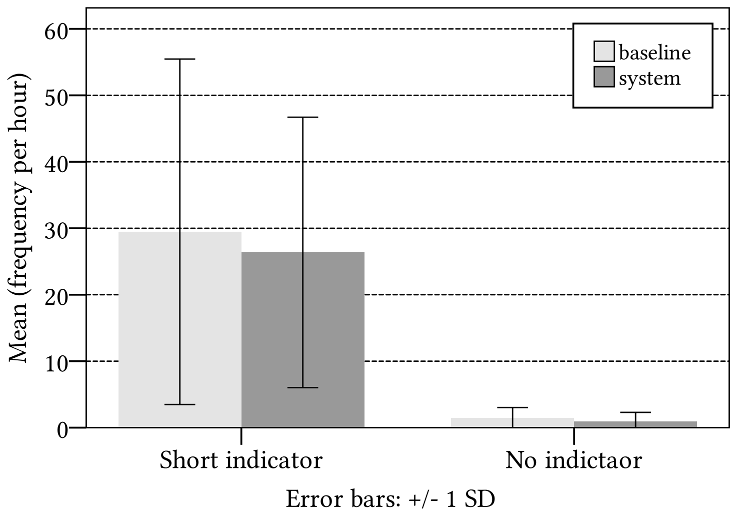


Figure 7.2.5. Discrete aggressive driving behavior use of indicators.

- **Flashing headlights**: on average, participants flashed their headlights .55 times per hour (SD = 2.98) when driving without the DFA and only .43 times per hour (*SD* = 1.90, *t(28)* = .55, *p* = .277, one-tailed, *d* = .10; Figure 7.2.6) under the system's influence. Despite a lack of statistical significance, this result is in the direction of H1.

- **Changing lanes in one go:** on average, participants changed lanes in one go 1.18 times per hour (*SD* = 2.32) in the baseline condition and only .41 times per hour (*SD* = .91) in the system condition, which is a significant decline (*t(28)* = 2.34, *p* = .013, one-tailed; Figure 7.2.6). With an effect size of *d* = .44, this is a moderate effect (Cohen, 1988). In the case of changing lanes in one go, H1 is accepted.

- **Verbal insult:** when driving without the DFA, on average, participants verbally insulted others on the road .97 times per hour (*SD* = 2.62). In comparison, they made only .61 insulting comments per hour (SD = 1.50) when driving with the system (*t(28)* = .82, *p* = .210, one-tailed, *d* = .15; Figure 7.2.6). This difference generally supports H1.

- **Insulting gestures:** insulting gestures were shown .15 times per hour (*SD* = .58) in the baseline condition but .31 times per hour (*SD* = 1.92) in the system condition (Figure 7.2.6). Like in the case of speeding and tailgating, this result is in the wrong direction. Therefore, the one-tailed test is not interpreted and H1 has to be rejected. Still, the two-tailed test shows that the increase, is not significant ($t(28) = -.58$, $p = .568$, two-tailed, $d = .11$).

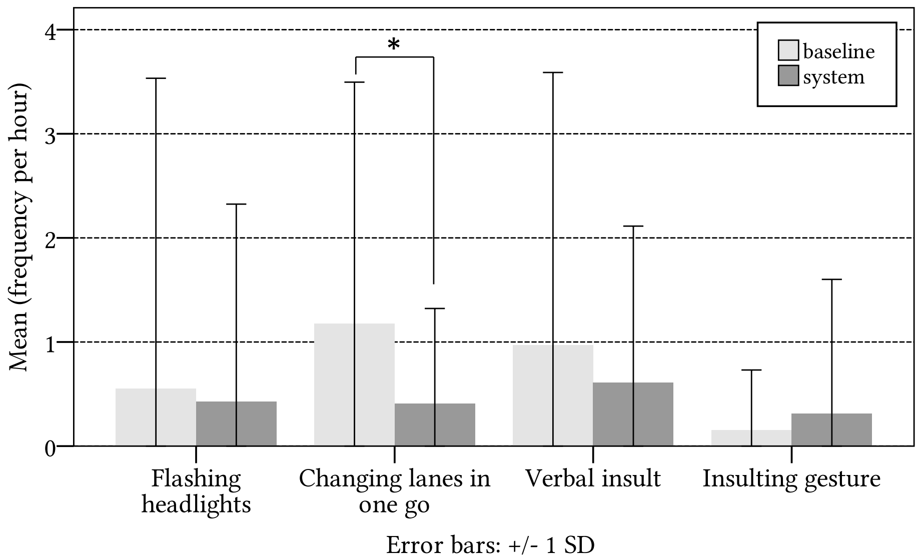


Figure 7.2.6. Discrete aggressive driving behaviors flashing headlights, changing lanes in one go, verbal insult, and insulting gestures.

To test hypothesis H1 across the behaviors, a score was determined by summarizing the frequencies of the eight behaviors and multiplying them with the severity values derived from the online study (*6.3 Study 4: Online* Survey). In the case of the continuous behaviors, ten seconds correspond to one unit. For example, if a participant was speeding 14 minutes per hour (840 seconds), this was equivalent to 84 units. This number was multiplied with a severity value of 1.24, which is the mean of the severity values for medium speeding (2.12) and strong speeding (.36). Participants reached an average score of 392.97 (*SD* = 208.68) when driving with the DFA and an average score of 341.05 (*SD* = 177.71) without the system. Since the score was higher under the system condition—which is contrary to the assumed direction—H1 has to be rejected across all behaviors. According to the post-hoc two-tailed t-test, the difference is not significant ($t(28) = -1.43$, $p = .164$, two-tailed, $d = .27$). Figure 7.2.7 depicts the development of the score when accumulating the individual behaviors in the ascending order of their influence, which is the product of their frequency and severity. It becomes clear that the two continuous behaviors speeding and tailgating, in particular, increased the score in the system condition.

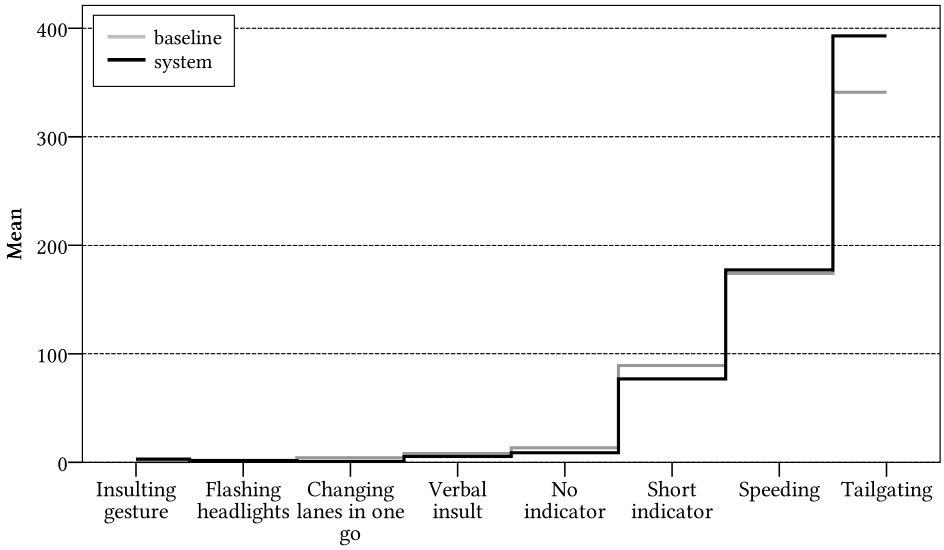


Figure 7.2.7. Accumulation of the aggressive driving score.

Perception

Hypotheses H2a, H2b, and H2c address the perception of the DFA and are tested based on the interview and questionnaire data.

- **Awareness of aggressive driving**: hypothesis H2a postulates that *the DFA raises an awareness of aggressive driving, in particular, of the behaviors that are fed back by the system.* In the interviews, participants named 13 different behaviors that they assumed were recognized by the DFA, only three of which were correct, including improper following distance/tailgating (17 participants), improper speed/exceeding the speed limit (9), and incorrect use of indicators (1). Five of the participants explicitly stated that they did not pay attention to the system; eight indicated that they did not notice the flashing instant feedback; and ten said that they did not observe a change in the appearance of the avatar. Considering the distracting aspects of the system, only the pulsating movements of the avatar were criticized by one participant (e.g., "The speed of the animation is too fast."). Thirteen participants explicitly stated that the system was not distracting and was easy to ignore (e.g., "You don't have to look at it, but you get feedback from the corner of your eye."). Two participants even recommended placing the avatar in the instrument cluster to make it more visible (e.g., "I would pay even more attention if the animation was displayed behind the steering wheel."). In conclusion, no participant was aware of all behaviors fed back by the DFA. Therefore, H2a can only be accepted for individual behaviors, including speeding, tailgating, and the incorrect use of indicators.

- **Gaming experience**: according to hypothesis H2b, *the DFA increases the gaming experience while driving*. To test this assumption, participants' gaming experience was compared within the conditions using a paired-sample t-test (Appendix 5.7 and Figure 7.2.8). The gaming experience was very high in both conditions (system: $M = 3.54$, $SD = .42$; baseline: $M = 3.47$, $SD = .41$), with higher values in a range between 1 and 5 indicating a better rating. Although the values were slightly higher when participants drove with the DFA, this difference is not significant ($t(31) = 1.00$, $p = .173$, one-tailed, $d = .17$). Therefore, H2b has to be rejected.

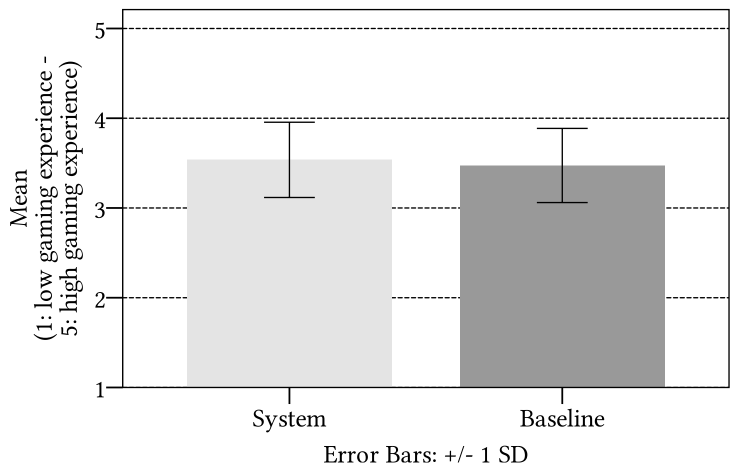


Figure 7.2.8. Gaming experience while driving.

Emotional attachment: the last hypothesis, H2c, states that *people feel emotionally attached to the DFA.* To test this hypothesis, the emotional attachment score was inspected that can have a value between 0 (no attachment) and 32 (high attachment). On average, participants reached a score of 22.56 (SD = 4.09, *min*: 13, *max*: 29; Figure 7.2.9), which is significantly above the theoretical average score of 16 ($t(31)$ = 9.08, p = .000, one-tailed). With an effect size of d = 1.60, this is a strong effect (Cohen, 1988). The high emotional attachment can mainly results from the assessment of the negative items (Figure 7.2.10), including "I have no feelings toward the avatar" (M = 1.44, SD = 1.39), "The avatar disappoints me" (M = .13, SD = .42), "The avatar makes me aggressive" (M = .00, SD = .00), "I am resentful of the avatar" (M = .19, SD = .64), and "I do not like the avatar" (M = .25, SD = .62). Since the negative items were transcoded, the closer their value is to zero, the more positive their impact on the score. In conclusion, H2c can be accepted since the emotional attachment was above average. This quantitative result was underpinned by some qualitative observations during the test drive. For example, four participants talked to the avatar when it was angry (e.g., "Oh, what's wrong with you?").

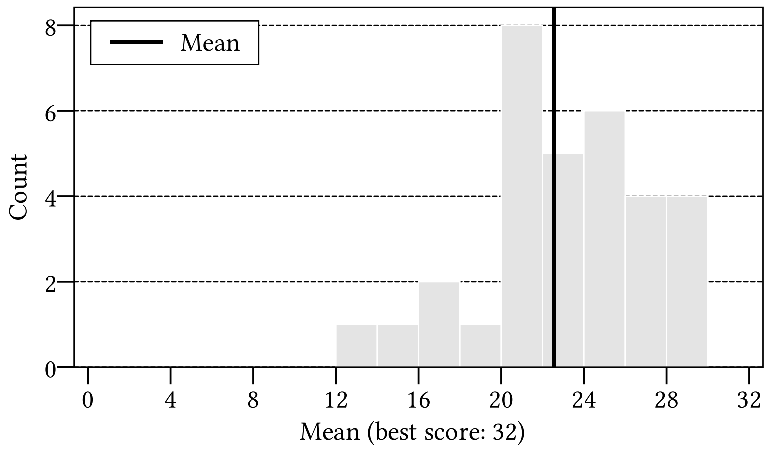


Figure 7.2.9. Emotional attachment to the DFA.

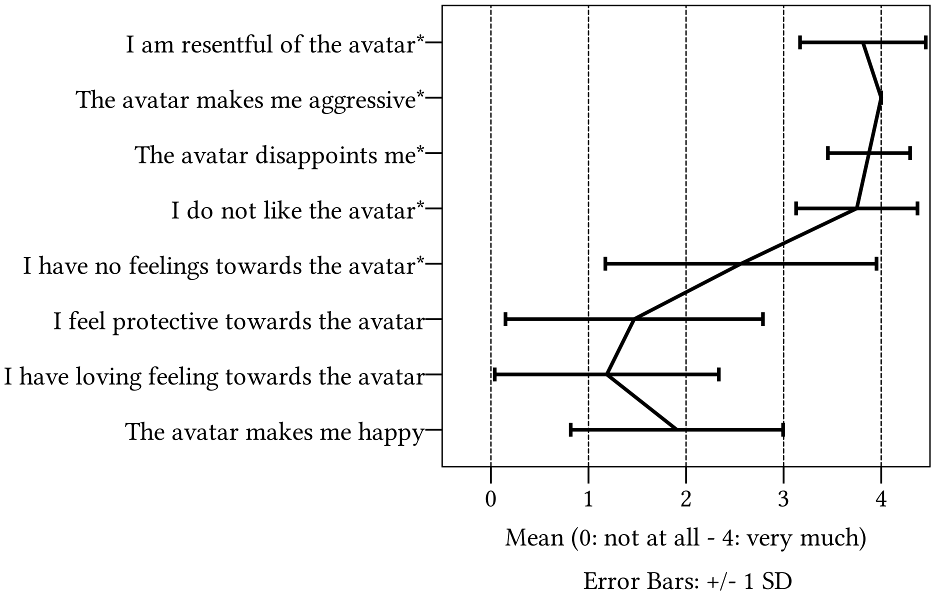


Figure 7.2.10. Items of the emotional attachment score (*transcoded).

- **Additional measures:** the user experience associated with the DFA was generally high (*M* = 2.81, *SD* = .94), with lower values between 1 and 7 representing a better rating (Appendix 5.6). On the sub-scales, the system received positive ratings for its hedonic quality (*M* = 3.04, *SD* = 1.14), pragmatic quality (*M* = 2.55, *SD* = .92), and attractiveness (*M* = 2.83, *SD* = 1.16). Considering the individual items, participants especially perceived the system as “easy” instead of “complicated” (*M* = 1.84, *SD* = .90). Regarding the perceived paternalism, it can be said that participants did not feel patronized by the system (*M* = 1.44, *SD* = .76), considering a scale from 1 “I did not feel patronized at all” to 7 “I felt very much patronized.” Thus, this factor is not seen as a confounding variable.

7.2.3 Conclusion and Discussion

In this chapter, the system developed, the DFA, was evaluated for its effectiveness (RQ5: *does the DFA mitigate aggressive driving effectively?*) and perception (RQ6: *how do people perceive the DFA?*). To answer the research questions, an experimental driving study with a WoZ prototype of the DFA was conducted. In a within-subjects design, 32 participants completed a test drive with the prototype (system condition) and without the prototype (baseline condition), while their driving behavior was automatically logged and manually annotated with a special focus on the driving behaviors fed back by the DFA. Moreover, participants provided interview and questionnaire data on the system's perception, including (i) the awareness of aggressive driving raised by the system, (ii) the gaming experience when interacting with the system, (iii) the emotional attachment toward the system, (iv) the user experience, and (v) perceived paternalism associated with the system. In line with RQ5, it was assumed that *the presence of the DFA reduces the frequency of aggressive driving behaviors, in particular, those that are fed back by the system* (H1). As the results showed, under the system's influence, some behaviors generally occurred less often (i.e., use of indicators, verbal insult, flashing headlight, changing lanes in one go), while others—contrary to expectations—were shown more frequently (i.e., speeding, tailgating, insulting gestures). Most of the increasing behaviors are continuous in nature (i.e., a sequence of actions over a period of time), whereas all of the decreasing ones count for discrete actions (i.e., a single action at a time). However, most of the comparisons within the individual behaviors did not reach statistical significance and had only small effects. Across all behaviors, however, it can be said that people did not drive less aggressively when the DFA was present. Therefore, H1 was rejected. The perception-related factors, including awareness, gaming experience, and emotional attachment, were seen as prerequisites for the effectiveness of the DFA. Hypothesis H2a assumed that *the DFA raises an awareness of the aggressive driving, in particular, of the behaviors that are fed back by the system.* Since no participant was aware of all relevant behaviors, H2a was rejected. Only the feedback on tailgating, speeding, and the incorrect use of indicators was correctly recognized by some participants. Hypothesis H2b postulated that *the DFA increases the gaming experience while driving.* H2b was not accepted, as the gaming experience was high under both conditions with no significant difference. Regarding the last prerequisite, it was hypothesized that *people feel emotionally attached to the DFA* (H2c). Since the emotional attachment was above average, H2c was accepted, showing even a strong effect. Beyond these prerequisites, the DFA was associated with a high level of user experience and did not elicit the feeling of being patronized.

Now, the open question is why there is no significant effect of the DFA on aggressive driving. At the beginning of this investigation, it was assumed that the DFA could be effective (i) if it makes the driver aware of aggressive driving, (ii) if it creates a high gaming experience for the driver, and (iii) if it evokes high emotional attachment in the driver. However, the DFA only met the prerequisite of emotional attachment. Therefore, it can be assumed that the system's effectiveness would have been higher if all prerequisites had been satisfied. In the following, the three factors as well as general limitations that might have influenced the effectiveness of the DFA are discussed. Thereby, methodological and design-related considerations are made.

Effectiveness

The first limitation that might have influenced the effectiveness of the DFA relates to the presence of the human annotator during the drive. According to the *passenger effect*, people drive safer when accompanied by others (Nakagawa et al., 2017). Although this influence was supposed to be controlled by having accompaniment on both test drives, and although the participants stated that they drove as usual, the annotator could have affected their driving in such a way that they acted (unconsciously) too conservative to show any change in aggressiveness.

Second, due to the fact that the participants knew that a CAN bus logger was monitoring their driving, the logger inherently served as a persuasive system (Paraschivoiu et al., 2019). Therefore, the effect of the DFA cannot be separated from the effect of the logger.

Third, it should be noted that the selection of the analyzed aggressive driving behaviors is not a validated metric of the construct but a technology-driven composition of potentially relevant behaviors. It cannot be ruled out that the selected behaviors measured something different than aggressive driving or that another set of behaviors would be a better indicator.

Fourth, the practical relevance of the DFA should be considered in relation to the empirical effect sizes revealed. Here, the study design and existing benchmarks should be taken into account (Fröhlich & Pieter, 2009; Pogrow, 2019). For example, one might think about a new training schedule with evaluations of professional athletes and hobby sportsmen. In both samples, the training reaches an effect size of $d = .45$. In the case of the hobby sportsmen, this can be interpreted as a trivial effect. In the case of the professional athletes, however, this effect has high practical relevance, since even small increases in performance are important (Fröhlich & Pieter, 2009). Likewise, the small effects of the DFA, whether being in the right or wrong direction, are trivial in a group of "normally" aggressive individuals, but are meaningful for pathologically or criminally aggressive drivers. To classify the participants according to their predisposition to drive aggressively, psychometric measures such as the *Driving Anger Scale* (Deffenbacher, Oetting, & Lynch, 1994) are needed. Moreover, the practical relevance of a small effect is given when an intervention beats an existing benchmark (Pogrow, 2019). As an exemplary benchmark, Krebs, Prochaska, and Rossi (2010) provide an meta-analysis of effect sizes in the context of computer-tailored interventions for improving health behavior. Overall, the effects of the persuasive systems considered are small to medium. Moreover, Hamari, Koivisto, and Pakkanen Behavior summarize that a lot of persuasive systems have no significant or even undesired effects (2014). In view of these findings, the practical importance of the DFA increases.

Fifth, according to the multi-factor model of aggressive driving, aggressive driving is triggered by the interplay of personality traits and situational factors associated with the blocking of the driver's goals, with the latter having a larger impact (Shinar, 1998). In the study, however, the presence of such triggers was neither controlled nor checked. Therefore, it could be that there were no triggers of aggression and the behavior shown was not actually aggressive driving.

Finally, despite a lack of significance, it is striking that most of the increasing behaviors are continuous in nature, while all decreasing behaviors are discrete actions. This finding suggests that the effectiveness of the DFA might depend on the type of behavior in question and points to the dual-processing of aggressive driving (Gawronski & Creighton, 2013).

Awareness of Aggressive Driving

More than half of the participants became aware of the feedback on tailgating, and around one third realized the feedback on speeding. However, hardly anybody noticed the feedback on the discrete behaviors. In summary, the DFA has not sufficiently raised participants' awareness of aggressive driving. This has two major consequences for the effectiveness of the DFA. In the case of the discrete behaviors, no association was made between the behavior and its consequences. Thus, there was no cognitive evaluation of and reflection on the behavior that might have triggered a change in behavior (Wilson et al., 2015). In the case of the continuous behaviors, the obvious feedback could have been perceived as a threat, for example, as a criticism of the driving style or unfair punishment. The participants could have responded to this threat with reactance in the form of increased aggression (Ehrenbrink & Prezenski, 2017). This outcome could explain the unexpected effect of continuous behaviors increasing under the system's influence.

From a design perspective, it might be assumed that the feedback was too unobtrusive to raise awareness. This problem could be solved by a more eye-catching design or the use of other feedback modalities, such as auditory or haptic notifications. In the context of ecological driving, studies have shown that the combination of visual and haptic feedback is particularly effective (Staubach et al., 2012)

From a methodological perspective, the functionality of the DFA was not explained to the participants in detail and their interaction time with the system was short, so that no mental model was developed and no learning effects occurred. To overcome these limitations, long-term investigations are needed.

Gaming Experience

The participants had a high gaming experience when driving with *and* without the DFA. This result indicates that the gaming experience was not caused by the system but by other factors present under both conditions. For example, driving itself—as kart racing games show (Webb, 2019)—is associated with playful experiences. Likewise, the participation in the study could have caused experiences similar to a game, such as excitement, challenge, feelings of mastery, or curiosity (Ferrara, 2013; Hall et al., 2018). In order to increase the gaming experience caused by the DFA, the system needs to incorporate more game-like features. In its current version, the DFA uses the game design elements feedback and avatar. However, there are a number of other gaming elements that could be used, including 3D-sceneries, narratives, reputations, points, ranks and levels, marketplaces and economies, competition and cooperation, or time pressure (Deterding et al., 2011). Here, guidelines for designing gamified applications for the automotive domain can help to consider issues such as driver distraction or spatial limitations (Diewald et al., 2014).

Emotional Attachment

The participants had an above-average emotional attachment toward the DFA since the system did not cause negative emotions, such as disappointment or aggression. Still, the system did not cause positive emotions either. The development of positive feelings may have suffered from the participants' short interaction time with the DFA during the study, which was less than 30 minutes. Assuming that emotional relationships with technology develop in a similar way to those between humans (Hertlein & Twist, 2018), longer and more complex interactions are required. This need becomes clear through the example of the relationships people have with their mobile phones. People always have their mobile phones with them, and they are used for a wide range of everyday tasks, such as getting up, managing finances, or chatting with friends (Fullwood, Quinn, Kaye, & Redding, 2017; Vincent, 2005). All of these tasks take place on a very emotional and personal level and promote deeper interactions. A first approach to increasing the emotional attachment toward the DFA is to enable longer, more complex, more emotional, and personalized interactions with the system, whether in the real world or the context of a study. Design guidelines that address a user's attachment to smartphones can provide some assistance for this purpose, such as in Thorsteinsson and Page (2014).

The investigation presented constitutes the last step in the HCD process on the way to an evaluated persuasive system to mitigate aggressive driving. The primary lesson learned through this investigation is that there is room for behavior change in cars using Persuasive Technology in the form of avatar-based feedback systems. However, in the context of aggressive driving, these changes are very sensitive and can shift in the opposite direction so that the system promotes aggressive driving. The challenge is to identify system features that cause reactance and to determine system requirements that prevent reactance. A first approach, which was applied by the DFA, is to promote the emotional and gamified nature of the system. However, these features must be further specified and expanded as they were not fully met with the final design of the DFA. Another lesson learned is that the interaction with avatar-based feedback systems needs *time*: the user needs time to understand how the feedback works and to establish an emotional bond with system. In the final chapter that follows, the dichotomy of discrete and continuous behaviors in Persuasive Technology, the issue of reactance toward feedback systems, and ways to promote emotional attachment to technology are discussed. These issues are relevant to the present thesis and also provide general contributions to the fields of Persuasive Technology and aggressive driving. Furthermore, design implications derived throughout this thesis are summarized and elaborated on, resulting in an initial design guideline for avatar-based feedback systems in the automotive domain.

VIII. CHAPTER

GENERAL CONCLUSION AND DISCUSSION

8.1 Conclusion

Aggressive driving is "a syndrome of frustration-driven instrumental behaviors which are manifested in: (a) inconsiderateness toward or annoyance of other drivers [...], and (b) deliberate dangerous driving to save time at the expense of others [...]" (Shinar, 1998, p. 139). Looking for a technology-driven and voluntary intervention to the problem of aggressive driving, the research objective was to *develop a Persuasive Technology solution to effectively mitigate aggressive driving*. Persuasive Technology refers to "computerized software or information systems designed to reinforce, change or shape attitudes or behaviors or both *without* using coercion or deception" (Oinas-Kukkonen & Harjumaa, 2008, p. 202). Thereby, the focus was on the highway context and "normal" people, who behave aggressively from time to time while behind the wheel. Theoretically, there are two ways to change aggressive driving: directly by influencing the behavior itself or indirectly by removing, altering, or preventing the triggers of aggression (Shinar, 1998).

In order to develop a usable solution, the design process followed the human-centered design (HCD) approach (Maguire, 2001). By involving potential end-users and relevant stakeholders, five empirical studies were conducted to analyze the wider context of the future system, produce a system solution, and evaluate this solution against relevant user requirements. The design processes started with two research questions regarding the wider context of the system: *what are the* *emotional triggers of aggression in modern driving* (RQ1), and *what are the interventions to change aggressive behavior in everyday situations* (RQ2)? In the following, the five investigations are summarized and relevant contributions are highlighted.

8.1.1 Summary of Empirical Research

RQ1 was examined in a naturalistic driving study (study 1). While driving in real traffic, 34 participant tracked their emotional experiences and the triggers of these experiences. Each trigger associated with a negative emotion was supposed to be a potential trigger of aggression. Answering RQ1, 75 distinct triggers of aggression were identified. They were assigned to 15 different types, each referring to an intrinsic source (e.g., personal issues or personal driving behavior) or an extrinsic source (e.g., traffic lights or other road users) in the driving situation. The most common trigger was the exposure to the illegal and illegitimate actions of other motorized road users, such as tailgating, slow driving, or throwing trash on the street.

To address RQ2, interviews with 15 experts dealing with human aggression professionally (e.g., psychotherapists, probation officers, and martial artists) were conducted (study 2). In answer to RQ2, 34 distinct interventions to regulate aggression in everyday life were derived. Later on, the interventions were classified by building an affinity diagram. On the top level of the diagram, a distinction is made between intrinsic interventions (initiated by the self) and extrinsic interventions (initiated by an object, the situation, or another person). On the subordinate level, the interventions are categorized according to the human system they are directed at, differentiating between physical, cognitive, motivational, social, and strategic interventions. The interventions themselves constitute the bottom level of the classification scheme. The identified interventions stand out due to their variety and assumed effectiveness.

Based on the findings of the studies 1 and 2, the aim was to generate innovative ideas to mitigate aggressive driving. For this, six ideation workshops with 108 participants were conducted (study 3). In the workshops, participants were presented with the identified triggers of aggressive driving and the anti-aggression interventions. Inspired by these findings, 158 ideas were generated by the participants and grouped into eight different clusters by the author. Among these clusters, the most important source of inspiration for the later system was the concept of the car as an intelligent and social agent that calms the driver down.

Inspired by this idea, the DFA evolved. The DFA is a visual in-car interface that provides the driver with feedback on his driving performance with a special focus on nine highway-specific aggressive driving behaviors, including (i) tailgating, (ii) speeding, (iii) not using the indicators before changing lanes, (iv) using the indicators shortly before changing lanes, (v) verbal insults, (vi) insulting gestures, (vii) flashing headlights, (viii) changing several lanes in one go, and (ix) passing a single continuous center line. The feedback is represented by the emotional state of an abstract avatar that resembles the Mercedes-Benz icon. Depending on the driver's behavior, the avatar gradually changes its emotional state. In the absence of aggression, the avatar is more relaxed (positive feedback). If the driver drives aggressively, the avatar becomes progressively angrier (negative feedback). These emotional states were modeled by animating the avatar in terms of color and dynamics, i.e., the redder (or bluer) the avatar appears, and the faster it moves, the angrier (or relaxed) it is. In addition, the driver receives instant feedback by the display flashing as soon as the system recognizes an aggressive action.

In an online survey, 1047 German respondents were asked about their first impression of the DFA (study 4). The major research question was *how do people evaluate the likeability, usefulness, and innovativeness of the DFA* (RQ3)? In addition, data on the severity of the aggressive driving behaviors considered by the system were collected, answering the research question of *how do people assess the severity of different aggressive driving behaviors* (RQ4)? This data was used to specify the feedback algorithm of the DFA by weighing the feedback provided, i.e., severe violations have a stronger negative impact on the avatar's well-being than milder ones. With regard to RQ3, the DFA was perceived as moderately attractive, useful, and innovative. The results addressing RQ4 revealed different severity values for each of the nine behaviors, with tailgating, verbal insult, and insulting gestures being the most severe behaviors.

Finally, in an experimental driving study (study 5), the DFA was evaluated in terms of its effectiveness (RQ5: *does the DFA mitigate aggressive driving effectively?)* and perception (RQ6: *how do people perceive the DFA?).* For this, a Wizard-of-Oz prototype of the system was implemented into a test vehicle. In a within-subjects design, 32 participants completed a test drive with and without the prototype on a public highway, while their driving behavior was logged. In addition, participants provided interview and questionnaire data on their perception of the system, focusing on (i) awareness of aggressive driving raised by the system, (ii) gaming experience while driving, (iii) emotional attachment to the system, (iv) user experience, and (v) perceived paternalism caused by the system. The first three factors were supposed to be prerequisites for the system's effectiveness. Under the system's influence, discrete behaviors generally decreased (i.e., use of indicators, flashing headlights, changing more than one lane in one go, and verbal insults). In contrast, continuous behaviors tended to increase (i.e., tailgating, speeding, and—counting for a discrete action—making insulting gestures). Thus, RQ5 has to be denied overall. In answer to RQ6, the system raised a significant awareness of tailgating and speeding, but not for the other behaviors fed back by the system. The emotional attachment was over average. The gaming experience was high but was not associated with the system. Moreover, the system created a high user experience and did not elicit the feeling of being patronized. In conclusion, the effectiveness of the DFA is unclear, which can be explained by the fact that some prerequisites that are supposed to moderate the effect of the DFA on the mitigation aggressive driving are not satisfied by the system design proposed.

8.1.2 Summary of Contributions

Even if the evaluation of the DFA constitutes the last (and maybe most memorable) step of the empirical part of this work, contributions to research and practice are made, above all, with the previous investigations. They paved the way for the development of the system, provide a holistic view of the problem of aggressive driving, and demonstrate the variety of methods of HCD (e.g., expert interviews, online and offline surveys, driving studies, and ideation workshops). The major contributions for Persuasive Technology, emotion research, and traffic science are stressed below.

First, the identified emotional triggers of aggression represent a wide range of design elements and use cases that provide inspiration for the development of a persuasive system to mitigate aggressive driving. For example, one might consider how to reduce the negative feelings caused by poor road conditions, or make waiting at a red traffic light a more pleasant experience.

Second, likewise, the classification scheme of anti-aggression interventions, including illustrative examples of how to regulate human aggression in various domains, also serves as a source of inspiration. The challenge is to transfer these interventions into technical solutions and take context-specific requirements into account. Moreover, this overview also gives researches and practitioners who are not professionals concerned with the management of aggression access to this issue.

Third, although the evaluation of the DFA revealed no significant and rather unexpected results, it points to future investigations such as the dichotomy of discrete and continuous behaviors in Persuasive Technology, the issue of reactance toward feedback systems, and ways to promote emotional attachment to technology. These issues are relevant in the context of the present thesis and also raise new research questions for Persuasive Technology, traffic research, and related disciplines. These future directions are detailed in section *8.2.2 Empirical Reflections.*

Fourth, throughout this work—from theory to empirical research to the discussion of findings—learnings regarding the design of an avatar-based feedback system to mitigate aggressive driving were made. These are summarized and elaborated on in section *8.2.3 Design Reflections.*

Finally, beyond the aforementioned scientific contributions, one should not forget the practical relevance of the DFA and its positive impact on the individual and social consequences of aggressive driving, related to the subjective experience of driving, personal health, driving safety, and traffic flow.

8.2 Limitations and Future Directions

The following sections discuss the methodological limitations of the empirical studies and outline future directions for research and practice. Thereby, references to the theoretical foundations of this work are made.

8.2.1 Methodological Reflections

Several limitations, which have been discussed in the individual studies, have to be considered when interpreting the findings of this thesis and its contributions. Beyond these constraints, this section discusses the critical methodological decisions on a meta-level.

Limitations regarding the Human-centered Design Process

According to the ideal of HCD, the design process should be done in an iterative fashion, i.e., the individual phases should be switched, conducted concurrently, and repeated until an optimal solution is found (Maguire, 2001). In the present work, however, the HCD process was carried out without jumping forward and back between the stages, which was at the expense of the optimal solution. Thus, at this point, the design process should be continued by initiating a second iteration based on the lessons learned from the evaluation of the DFA (study 5).

Another constraint refers to the users and stakeholders involved in the design process. What is critical for both is their strong association with Mercedes-Benz, either as drivers of a Mercedes-Benz car or employees of the Daimler Group. This applies to the samples of the two driving studies (study 1 and 5) and the participants of the ideation workshops (study 3). In consequence, a rather homogenous group was involved in the development and evaluation of the DFA so that it is assumed that the system primarily matches the needs of a special group of people.

Balance between Internal and External Validity

A general issue in Human-Computer-Interaction (HCI) is the challenge of balancing experimental standardization (internal validity) and generalization (external validity). While HCI claims for framing research activities within the real world to increase relevance and realism, behavioral science, in general, insists on experimental validity to examine the effectiveness of a behavioral intervention (Lew, Nguyen, Messing, & Westwood, 2011; Zimmerman, Forlizzi, & Evenson, 2007). In view of the present work, this discussion mainly concerns the experimental driving study (study 5). Conducted in real traffic, the findings provide high external validity. However, the internal validity is limited. First, due to the realistic conditions, the controllability, reproducibility, and standardization of the experimental setup were not guaranteed (de Winter et al., 2012). Second, the construct of aggressive driving was operationalized by a non-validated metric, consisting of nine different aggressive driving behaviors that are supposed to be an indicator of the construct. Due to the missing validation, it cannot be ruled out that the selected behaviors measured something different than aggressive driving or that another set of behaviors would be better indicators. In order to increase the internal validity, the experimental setup should be replicated in a simulator study, and the proposed metric to capture aggressive driving should be validated empirically in advance.

Need for Long-term Studies

The need for long-term investigations has been demonstrated multiple times during this work. First, the HCD process should be iterated until an optimal solution is found. Second, given the naturalistic driving study (study 1), a long-term investigation could have resulted in a wider range of emotional triggers of aggression. Finally, it takes a long time for behavioral changes to show up, for emotional attachment to be established, and for mental models to be developed (Lally, van Jaarsveld, Potts, & Wardle, 2010)—all of which were examined in the experimental driving study (study 5). In conclusion, the mitigation of aggressive driving using Persuasive Technology is a perennial issue, which should be reflected in long-term research activities.

8.2.2 Empirical Reflections

The empirical discussion focuses on the dichotomy of discrete and continuous behaviors in Persuasive Technology, the issue of reactance toward feedback systems, and ways to promote emotional attachment to technology. These issues were uncovered with the evaluation of the DFA and imply relevant considerations for future research. Moreover, the DFA is discussed in the context of the *theory of operant conditioning* (Skinner, 1963).

Dual-Processing of Discrete and Continuous Behavior

Under the influence of the DFA, discrete aggressive driving behaviors generally decreased, while continuous ones tended to increase. In reference to the theoretical foundations of this work, the discrete-continuous distinction reminds of the dichotomy of human processing proposed in dual-process theories, leading to the assumption that both types of behavior are processed in different ways. (Frankish, 2010; Gawronski & Creighton, 2013). A large body of literature on dual-process theories has emerged over the past decades. However, no approach explicitly addresses the processing of discrete and continuous behavior. Thus, this section introduces three perspectives that underpin the assumed dichotomy of discrete and continuous behavioral processes in Persuasive Technology: (i) the distinction between *controlled and automatic human information processing* (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977), (ii) the *four horsemen of automaticity* (Bargh, 2014), and (iii) the *intertwined process cognitive-affective model* (James Price Dillard & Shen, 2005).

Shiffrin and Snyder (1977) provide one of the most fundamental work in the field of dual-processing where they differentiate between controlled and automatic processes. They define automatic processes “as the activation of a sequence of nodes” (Schneider & Shiffrin, 1977, p. 2) by an internal or external stimulus without the individual’s active control or attention. In contrast, controlled processes are “a temporary sequence of nodes activated under control of, and through attention by, the subject” (Schneider & Shiffrin, 1977, p. 2). Due to the temporal component, these modes provide an initial definition of discrete and continuous behavior. Discrete behavior, which is seen as a single action at a time, corresponds to the understanding of controlled processes. Continuous behavior, which is a sequence of actions enacted over a period of time, refers to the automatic mode. What still has to be answered is whether discrete and continuous driving behaviors fulfill the same attributes as automatic and controlled processes in general. Thus, it has to be checked whether *discrete aggressive driving behavior occurs under the active control and attention of the driver*, and whether *continuous aggressive driving behavior occurs without the driver’s active control and attention.*

The four horsemen of automaticity model contradicts the strict distinction between controlled and automatic processes, claiming that some processes are neither exclusively automatic nor exclusively controlled (Bargh, 2014). There are three types of automaticity that differ in their level of awareness, efficiency, intentionality, and controllability—the four horsemen. Awareness refers to the conscious perception of the stimulus that triggers human processing, the process itself, or the consequences of the process; efficiency relates to the amount of cognitive resources required for the process; intentionality describes the control over the instigation of the process; and controllability is the ability to stop or alter a process after its initiation. Consequently, the first type of automaticity is pre-conscious automaticity, whereby the individual becomes aware of a stimulus in the environment but is not motivated to further process it. A subset of pre-conscious automaticity is subliminal perception referring to stimuli that are transferred below the level of conscious awareness. Subliminal perception does not require cognitive resources so that the use of subliminal persuasive feedback for in-car systems is supposed to be a promising approach to increase road safety (Riener, 2012). The second type, post-conscious automaticity, refers to processes that are conscious and temporary, and only occur when the stimulus contains some relevance to the individual. Post-conscious automaticity also explains the phenomenon of priming. Priming can be observed when the exposure to a stimulus influences judgments that directly follow (Bargh, 2014). Finally, goal-dependent automaticity describes processes that only occur under the individual's intention and control. Since the DFA is aimed at increasing the driver's awareness of certain behaviors, there is a link to the construct of awareness. Many participants recognized the feedback on tailgating and speeding, both of which increased under the system's influence. However, hardly anybody was aware of the feedback on the discrete behaviors. Discrete behaviors were shown less often under the influence of the DFA (even if this effect was not significant), which could indicate subliminal persuasion. This leads to the assumption that *depending on whether the feedback creates awareness of the concerned driving behavior or not, both discrete and continuous behavior can be processed pre-consciously, post-consciously, or goal-directed.*

The intertwined process cognitive-affective model is a model of reactance in HCI (James Price Dillard & Shen, 2005). The theory of psychological reactance proposes that, when an individuals' freedom is threatened, reactance is activated, which motivates him to restore or compensate for the loss or reduction of autonomy (Brehm, 1966; Ehrenbrink & Prezenski, 2017; Steindl et al., 2015). The intertwined process cognitive-affective model starts with a perceived threat of freedom or control and focusses on its cognitive and affective consequences. On the one side, the threat leads to cognitive processes that are aimed at reestablishing the lost freedom or control, such as talking up the threat, derogating the source of the threat, denying the existence of the threat, or realizing freedom in a different way. On the other, the threat elicits anger or another negative affective state, which, in turn, leads to aggressive behavior. Both cognitive and affective processes are intertwined (James Price Dillard & Shen, 2005). Also driving feedback can be interpreted as a threat, for example, if it is perceived as unfair or as a criticism of one's driving skills (Uludag, 2014), if it is patronizing (Spiekermann & Pallas, 2006), or if the driver does not understand what the feedback is for (Bar-Anan et al., 2009). In the case of the DFA, participants were aware of the feedback on the continuous behaviors but not on the discrete ones. Consequently, only the feedback on the continuous behaviors could be perceived as a threat and cause reactance, which is evident in the general increase of this type of behavior. Moreover, the respondents of the online survey (study 4) were afraid that the DFA could amplify aggressive responses, which supports the assumption that the feedback was threatening. In conclusion, this leads to the assumption that *if driving feedback is perceived as a threat to freedom by the driver, this leads to reactance and increased aggression. The risk of being perceived as a threat is especially high for punishing feedback. If driving feedback is not perceived as a threat to freedom, this leads to a change of the behavior fed back.*

In summary, the processing modes automatic and controlled provide an initial definition of discrete and continuous aggressive driving behavior (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977); the three types of automaticity describe how these behaviors might be processed (Bargh, 2014); and the intertwined process cognitive-affective model shows how driving feedback can lead to reactance (James Price Dillard & Shen, 2005). While all of these approaches were considered separately in the present discussion, the challenge for future research will be to develop an integrated approach that explains the dichotomous processing of discrete and continuous aggressive behavior and the consequences for behavior change.

Increasing Emotional Attachment

Although the participants' emotional attachment toward the DFA was above average, it is a challenge to create a deeper emotional bond. The limiting factors were the interaction possibilities and the interaction time with the system. The interaction possibilities were delimited due to the risk of driver distraction and the reduced freedom of movement in the car (Horberry et al., 2006). This prevented complex interactions (e.g., deep talks) as well as interactions that require intensive physical activity (e.g., walking around). In the following, two design implications are proposed that are supposed to promote the development of emotional attachment in systems under limited temporal and spatial conditions: (i) the implementation of human-like attributes beyond emotions, and (ii) the concept of personalization.

The unique feature of the DFA is its capacity to express emotions. The implementation of emotions into a system is a form of anthropomorphism. Anthropomorphism is defined as the attribution of human-like characteristics to non-human objects (Bartneck et al., 2009; Richert et al., 2018; Yuan & Dennis, 2019). The level of anthropomorphism positively correlates with the emotional attachment toward the system (Rauschnabel & Ahuvia, 2014). In order to increase this effect in the case of the DFA, anthropomorphic features other than emotions could also be implemented. For example, visual human-like characteristics of electronic consumer products increase the emotional attachment toward them and, in turn, people's willingness to pay for them (Yuan & Dennis, 2019). In the field of social robotics, it was shown that also anthropomorphic attributes such as a name or a personal history have a positive effect on people's emotional response toward the robot, in this case, the tendency to strike it (Darling, 2015).

Moreover, emotional attachment also benefits from personalization, which is the process of changing a product's appearance or functionality in favor of its relevance to the user. By personalizing a system, the person invests effort in it, such as time, energy, or attention, which creates an emotional bond (Mugge, Schoormans, & Schifferstein, 2009). The positive effect of personalization on emotional attachment was shown for a variety of products, ranging from bicycles (Mugge et al., 2009) to game avatars (Ducheneaut, Don Wen, Yee, & Wadley, 2009). In the case of the DFA, two features can be personalized: the feedback and the avatar. The driver could personalize the representation of the feedback (abstract vs. concrete), the timing (instant or summarized), the output modality (e.g., display, lightning systems, sound systems), or specific design features (e.g., color, brightness, size). The avatar could be personalized by creating a personal avatar or giving the avatar a name. Through personalization, also culture-, age-, and context-specific user requirements can be addressed. For instance, it is known that Asian countries prefer cartoon-like avatars compared to Western countries (Yoon & Vargas, 2016). Likewise, older adults favor cartoon-like avatars, while younger adults and teenagers want clean designs (Rice et al., 2013).

Feedback and Operant Conditioning

In principle, feedback is a performance indicator based on the outcome of an enacted intention or habit (Wilson et al., 2015). By providing the individual with feedback on his performance, he can make associations between the behavior in question and its consequences. This association may trigger the cognitive evaluation of the behavior and, in turn, cause a change. In doing so, feedback increases or decreases the likelihood of a certain behavior, which is a form of operant conditioning (Skinner, 1963). The theory of operant conditioning is based on the idea of presenting or removing an aversive or favorable stimulus after a certain behavior in order to strengthen or weaken it. Four forms of conditioning are possible: positive reinforcement, negative reinforcement, positive punishment, and negative punishment. Reinforcement increases the likelihood of the behavior in question, while punishment decreases it. Positive means that a stimulus is added, while negative indicates its removal. In positive reinforcement (or reward), the behavior is followed by a favorable stimulus. Negative reinforcement occurs when an aversive stimulus is removed after the occurrence of the behavior. In contrast, negative punishment refers to removing a favorable stimulus after the behavior has occurred. Finally, positive punishment occurs when an aversive stimulus is presented after the behavior in question (McConnell, 1990; Skinner, 1963).

The positive and negative feedback provided by the DFA can be seen as a favorable or aversive stimulus, respectively. The active provision of negative feedback on aggressive behavior is a manifestation of positive punishment. In contrast, prosocial behavior was negatively reinforced by removing the negative feedback, which refers to negative reinforcement. However, for both feedback variants to have an effect, it must be ensured that the positive (or negative) feedback is actually perceived as an aversive (or favorable) stimulus. In the context of the DFA, it might be the case that the participants preferred the visualization of negative feedback (i.e., the angry state of the avatar that is associated with red and fast movements), compared to the positive feedback (i.e., the relaxed state of the avatar that is associated with blue and slower movements). Although it was confirmed that the participants interpreted the emotional states of the avatar correctly according to their intended valence *(6.2.3 Avatar and Feedback Design),* they were never asked for their aesthetic perception of the different visualizations. Thus, even if the angry state was intended to be an adverse stimulus by the author, it might be the case that participants aesthetically were in favor of this visualization. In consequence, the avatar's angry state (unconsciously) functioned as a positive reinforcement instead of a positive punishment, which would provide an explanation for the increase of aggressive driving. In conclusion, this raises the question concerning *the motivation of people to care for a* *certain emotional state of a virtual avatar as well as the discussion of the relevance of aesthetics as a reward.*

8.2.3 Design Reflections

From theory to empirical research to the discussion of findings, a number of insights were gained that can be (or already have been) applied to the design of the DFA and similar systems. In the following, these considerations are summarized and elaborated on to provide an initial design guideline for the development of an avatar-based feedback system to mitigate aggressive driving. However, the implications proposed are neither final nor complete, encouraging researchers and practitioners alike to refine and expand on them.

- **Visual feedback:** the overall positive assessment of the visual design of the DFA in terms of driver distraction and unobtrusiveness supports the choice for a visual solution. At this point, the challenge is to design the feedback in such a way that it creates an awareness of the behavior in question without being disruptive. While focal visual interfaces (e.g., the instrument cluster display) generate the necessary awareness, peripheral visual interfaces (e.g., lighting systems) are less obtrusive (Campbell et al., 2016; Paraschivoiu et al., 2019).
- **Anthropomorphism**: a driver's emotional attachment toward the system can foster prosocial behavior, prevent reactance, and promote long-term usage. A possibility to increase emotional attachment is to implement human-like attributes into the system, including physical characteristics, motivations, intentions, or emotions (Bartneck et al., 2009; Richert et al., 2018; Yuan & Dennis, 2019). For this, abstract or metaphorical representations of the feedback should be used (Paraschivoiu et al., 2019).
- **Personalization**: another way to increase emotional attachment is to give the driver the possibility to personalize the system (Mugge et al., 2009). This can be done, for example, by configuring feedback features according to personal preferences (e.g., representation, timing, modality, design). If an avatar is used as a design element, the avatar itself could be personalized, for example, by creating an individualized avatar or by giving it a name.
- **Avoid positive punishment:** driving feedback provided by a system can lead to reactance and increased aggression if the

feedback is perceived as a threat (Brehm, 1966; Ehrenbrink & Prezenski, 2017; Steindl et al., 2015). This is the case when aggressive behavior is punished with negative feedback. Thus, it is recommended to reward the desired behavior with positive feedback and to remove this reward if aggressive behavior is shown (Skinner, 1963; Wilson et al., 2015). It is important to note that one needs to check whether the user likes the design of the positive feedback so that is can function as a reward.

- **Social Gamification:** the DFA incorporates the Gamification elements of avatar and feedback. Besides, there are a number of other elements that could be used (Deterding et al., 2011). When it comes to socially motivated changes in behavior, such as aggressive driving, it is recommended to use social Gamification elements, including guilds or teams, social networks, social comparison, social competition, and social discovery (Tondello et al., 2016). For example, Soroa, Wollstädterb, and Rakotonirainya (2014), present the so-called *driving behavior badges*. The in-car application compromises the idea to collect color badges depending on the driving behavior. For good driving, the driver receives green badges, for bad driving, he receives red ones. Amber colored badges indicate an average driver. The badges are earned based on other drivers' votes. For this, every car in the community has a button on the steering wheel that can be pressed to vote for another driver nearby. The badges and the corresponding driving score are presented to the driver as well as the other community members in the head-up display.

- **Feedback explanations:** for the most effective feedback, the driver should be provided with both instant and summarized information on his driving performance (Addalena & Aras, 2005). While instant feedback raises an awareness of the behavior intended to be changed, summarized feedback helps to monitor the progress in performance. In any case, it is essential that the driver understands which behaviors are fed back and why in order to establish a cognitive link between the behavior and the feedback (Wilson et al., 2015). For this, the feedback should contain an explanatory component. Instant feedback, for example, could be enriched by icons or short textual instructions that direct the driver's attention to the relevant behavior, point out the gap between the current and the desired behavior, or provide information on how to correct the behavior (Chan & Ng, 2009; Feng & Donmez, 2013). Summarized feedback should make explicit the behaviors that are being considered. A practical example that combines abstract feedback and discrete explanations is the eco interface developed by Renault (Figure 8.2.1). The system includes a concrete feedback in the form of a numerical score that is based on different parameter such as acceleration, gear change, or braking. Each parameter is visualized through a progress bar so that the driver knows which parameters are relevant for the score. In addition, an abstract representation of this score is given in the form of a leaf that grows in accordance with the score.

Figure 8.2.1. Renault's (2019) eco interface.

- **(Additional) mobile solution:** some of the previous ideas cannot be implemented in the car without risk as they increase driver distraction. These implications encourage a mobile solution of the system that can be used while standing or outside the car. Another benefit of a mobile solution is the extended interaction time, which, in turn, might increase the driver's attachment to the system. When implemented into a smartphone, the system might also benefit from the extraordinary relationship people have with their mobile phones, which could be transferred to the system (Vincent, 2005).

8.3 Outlook and Closing Words

Motivated by the individual consequences (i.e., decreasing pleasure of driving and personal health) and social consequences (i.e., increasing traffic accidents and congestion) of aggressive driving, the research objective of this doctoral thesis was to *develop a Persuasive Technology solution to mitigate aggressive driving*. As a solution, the DFA evolved. The DFA is a visual in-car interface that provides the driver with feedback on his driving performance with a special focus on highway-specific aggressive driving behaviors. The feedback is represented through the emotional state of an abstract avatar—resembling the Mercedes-Benz star—that changes its emotional state depending on the driver's behavior. With the idea of the DFA, this work has shown that there is room for mitigating aggressive driving through Persuasive Technology. The contribution of this thesis is not only the system proposed, but also the holistic investigation of aggressive driving. Despite all contributions, there is a need for future research. Thus, this thesis wants conclude with an outlook on future research and design activities in the field of traffic research and Persuasive Technology.

First, the focus of this work was on the highway context. However, aggressive driving can also be observed in the city, in residential areas, or on country roads, which raises the questions of persuasive solutions to mitigate aggressive driving in these contexts.

Second, due to the design focus of this work, the theoretical foundations, such as the multi-factor model of aggressive driving and the assumption of direct and indirect behavior change in the context of aggressive driving (Shinar, 1998), were not empirically investigated. Future research, however, should do so to draw conclusions about the effectiveness of the DFA and similar systems.

Third, traffic research lacks a validated metric for measuring aggressive driving based on objective behavioral data. This work provides an initial attempt to establish such a metric that claims for further investigations.

Fourth, the proposed design guideline with a focus on avatar-based feedback systems in the automotive domain wants to motivate future research and design activities. On the one side, the implications contained are neither final nor complete, encouraging researchers and designers to refine and expand on them. On the other side, the implications can serve as an inspiration for the development of

Persuasive Technology in other contexts related to aggression, making it necessary to adapt them.

Finally, the assumption that discrete and continuous behavior is processed in different ways by humans is a relevant issue in the field of Persuasive Technology. This assumption requires experimental investigations as well as the development of a dual-process model in this context.

As long as we drive manually, the issue of aggressive driving is an omnipresent problem on our roads. This work has shown that there is room to change aggressive behavior through Persuasive Technology in the form of an avatar-based feedback system. However, this work has also shown that changing aggressive driving is a sensitive issue and that the design of appropriate technology-driven interventions has to be well thought out in order to achieve the intended effects. Thus, this work wants to encourage researchers and practitioners concerned with the problem of aggressive driving to add this challenge to their agendas and, in doing so, enhance the subjective experience of driving, improve personal health, and contribute to the steady traffic flow and safety of our roads.

REFERENCES

AAA Foundation for Traffic Safety. (2016). Prevalence of Self-Reported Aggressive Driving Behavior: United States, 2014. Retrieved March 13, 2020, from https://aaafoundation.org/prevalence-self-reported-aggressive-driving-behavior-united-states-2014/

Addalena, M., & Aras, T. (2005). Assessment - summative and formative - some theoretical reflections. *British Journal of Educational Studies*, *53*(4), 466–478.

Adell, E., Várhelyi, A., & Hjälmdahl, M. (2008). Auditory and haptic systems for in-car speed management – A comparative real life study. *Transportation Research Part F: Traffic Psychology and Behaviour*, *11*(6), 445–458.

Ajzen, I. (1985). From Intentions to Actions: A Theory of Planned Behavior. In J. Kuhl & J. Beckmann (Eds.), *Action Control* (pp. 11–39). Berlin, Heidelberg: Springer.

Alberola, C., Brau, H., & Walter, G. (2017). Die Kürzung des User Experience Questionnaire UEQ. In M. Burghardt, R. Wimmer, C. Wolff, & C. Womser-Hacker (Eds.), *Tagungsband Mensch und Computer 2017* (pp. 37–48). Regensburg: Gesellschaft für Informatik e.V.

Alonso, F., Esteban, C., Montoro, L., & Serge, A. (2019). Conceptualization of aggressive driving behaviors through a Perception of aggressive driving scale (PAD). *Transportation Research Part F: Traffic Psychology and Behaviour*, *60*, 415–426.

Anagnostopoulou, E., Bothos, E., Magoutas, B., Schrammel, J., & Mentzas, G. (2016). *Persuasive Technologies for Sustainable Urban Mobility*. Retrieved from http://arxiv.org/abs/1604.05957

Arroyo, E., Sullivan, S., & Selker, T. (2006). CarCOACH: A polite and effective driving COACH. In *Extended Abstracts of the CHI 2006 Conference on Human Factors in Computing Systems* (pp. 357–362). New York: ACM.

Atkinson, B. M. C. (2006). Captology: A Critical Review. In W. IJsselsteijn, Y. de Kort, C. Midden, B. Eggen, & E. van den Hoven (Eds.), *Proceedings of the PERSUASIVE 2006 Conference on Persuasive Technology, LNCS, vol. 3962* (pp. 148–159). Berlin, Heidelberg: Springer.

Bakeman, R. (2005). Recommended effect size statistics for repeated measures designs. *Behavior Research Methods*, *37*(3), 379–384.

Bar-Anan, Y., Wilson, T. D., & Gilbert, D. T. (2009). The Feeling of Uncertainty Intensifies Affective Reactions. *Emotion*, *9*(1), 123–127.

Baregheh, A., Rowley, J., & Sambrook, S. (2009). Towards a multidisciplinary definition of innovation. *Management Decision*, *47*(8), 1323–1339.

Bargh, J. A. (2014). The Four Horsemen of Automaticity: Awareness, Intention, Efficiency, and Control in Social Cognition. In J. Robert S. Wyer & T. K. Srull (Eds.), *Handbook of Social Cognition. Volume 1: Basic Processes* (2nd ed., pp. 1–40). New York, London: Psychology Press.

Baron, R. A., & Byrne, D. (1987). *Social psychology: Understanding human interaction* (5th ed.). Boston: Allyn & Bacon.

Bartneck, C., Croft, E., & Kulic, D. (2009). Measuring the anthropomorphism, animacy, likeability, perceived intelligence and perceived safety of robots. *International Journal of Social Robotics*, *1*, 71–81.

Berkowitz, L. (1989). Frustration-Aggression Hypothesis: Examination and Reformulation. *Psychological Bulletin*, *106*(1), 59–73.

Biran, B. (2014). *Gamify: How gamification motivates people to do extraordinary things.* New York: Bibliomotion.

BMW. (2020). BMW ConnectedDrive. Retrieved February 7, 2020, from https://www.bmw.de/de/topics/service-zubehoer/connecteddrive/bmw-connected-drive-uebersicht.html

Braun, M., Chadowitz, R., & Alt, F. (2019). User Experience of Driver State Visualizations: a Look at Demographics and Personalities. In D. Lamas, F. Loizides, L. Nacke, H. Petrie, M. Winckler, & P. Zaphiris (Eds.), *Proceedings of the INTERACT 2019 Conference on Human-Computer Interaction, LNCS, vol. 11749* (pp. 158–176). Cham: Springer.

Brehm, J. W. (1966). *Theory of psychological reactance.* New York: Academic Press.

Brem, A. (2019). Creativity on Demand: How to Plan and Execute Successful Innovation Workshops. *IEEE Engineering Management Review*, *47*(1), 94–98.

Breuer, J., & Elson, M. (2017). Frustration-Aggression Theory. In P. Sturmey (Ed.), *The Wiley Handbook of Violence and Aggression* (pp. 1–12). https://doi.org/10.1002/9781119057574.whbva040

Bundesministerium für Verkehr und digitale Infrastruktur. (2020). Alles über Verkehrssicherheit. Runter vom Gas. Retrieved February 7, 2020, from https://www.runtervomgas.de/

Bundesministeriums der Justiz und für Verbraucherschutz. (2016). *Straßenverkehrs-Ordnung vom 6. März 2013, zuletzt geändert durch Art. 2 V v. 16.12.2016 I 2938 (BGBl. I S. 367).* Retrieved from https://www.chip.de/downloads/StVO-Strassenverkehrsordnung-PDF_110284662.html

Burns, P. C., Andersson, H., & Ekfjorden, A. (2000). Placing Visual Displays in Vehicles: Where should they go? In *Proceeding of the ICTTP 2000 International Conference on Traffic and Transportation Psychology*. Berne: Swiss Council For Accident Prevention.

Byrne, S., Gay, G., Pollak, J. P., Retelny, D., Gonzales, A. L., Lee, T., & Wansink, B. (2012). When I Eat so Bad, my Pet Looks so Sad. *Journal of Children and Media*, *6*(1), 83–99.

Cackowski, J. M., & Nasar, J. L. (2003). The restorative effects of roadside vegetation: Implications for automobile driver anger and frustration. *Environment and Behavior*, *35*(6), 736–751.

Calaguas, G. M. (2012). The Correlation between Peer Aggression and Peer Victimization: Are Aggressors Victims Too? *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, *6*(8), 531–

535.

Campbell, J. L., Brown, J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Sanquist, T., … Morgan, J. F. (2016). *Human Factors Design Guidance For Driver-Vehicle Interfaces*. Washington, D.C.: National Highway Traffic Safety Administration.

Chan, A. H. S., & Ng, A. W. Y. (2009). Perceptions of implied hazard for visual and auditory alerting signals. *Safety Science*, *47*(3), 346–352.

Charamel. (2019). Effizientere Bedienung in Fahrzeugen mithilfe von Avataren. Retrieved December 26, 2019, from https://www.charamel.com/case-studies/avatareinsatz-in-fahrzeugen

Clarke, T., & Costall, A. (2008). The emotional connotations of color: A qualitative investigation. *Color Research and Application*, *33*(5), 406–410.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). New Jersey: Lawrence Erlbaum Associates.

Cooper, J. (2020, February 10). Road rage driver jailed after terrifying attack on motorist on Devon road. *Devon Live*. Retrieved from https://www.devonlive.com/news/devon-news/road-rage-driver-jailed-after-3828837

Crispim, A. C., Cruz, R. M., Baasch, D., Amorim, L., Trevisan, R. L., & Da Silva, M. A. (2015). Measurement of Affect: From Theoretical and Instrumental Perspectives. *Psychology Research*, *5*(2), 96–107.

Dahlinger, A., Wortmann, F., Ryder, B., & Gahr, B. (2018). The Impact of Abstract vs. Concrete Feedback Information on Behavior – Insights from a Large Eco-Driving Field Experiment. In *Proceedings of the CHI 2018 Conference on Human Factors in Computing Systems* (pp. 379–390). New York: ACM.

Darling, K. (2015). “Who’s Johnny?” Anthropomorphic framing in human-robot. In P. Lin, K. Abney, & R. Jenkins (Eds.), *Robot Ethics 2.0: From Autonomous Cars to Artificial Intelligence* (pp. 173–188). New York: Oxford University Press.

Day, A. (2009). Offender emotion and self-regulation: implications for offender rehabilitation programming. *Psychology, Crime & Law*, *15*(2–3), 119–130.

de Winter, J. C. F., van Leeuwen, P. M., & Happee, R. (2012). Advantages and Disadvantages of Driving Simulators: A Discussion. In A. Spink, F. Grieco, O. Krips, L. Loijens, L. Noldus, & P. Zimmerman (Eds.), *Proceedings of the Measuring Behavior 2012 Conference on Methods and Techniques in Behavioral Research* (pp. 47–50). Wageningen: Noldus Information Technology.

Deffenbacher, J. L. (2016). A review of interventions for the reduction of driving anger. *Transportation Research Part F: Traffic Psychology and Behaviour*, *42*(2), 411–421.

Deffenbacher, J. L., Lynch, R. S., Oetting, E. R., & Yingling, D. A. (2001). Driving anger: Correlates and a test of state-trait theory. *Personality and Individual Differences*, *31*(8), 1321–1331.

Deffenbacher, J. L., Oetting, E. R., & Lynch, R. S. (1994). Development of a Driving Anger Scale. *Psychological Reports*, *74*(1), 83–91.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining “gamification.” In *Proceedings of the MindTrek 2011 Conference on Envisioning Future Media Environments* (pp. 9–15). New York: ACM.

Diewald, S., Möller, A., Stockinger, T., Roalter, L., Koelle, M., Lindemann, P., & Kranz, M. (2014). Gamification-supported Exploration and Practicing for Automotive

User Interfaces and Vehicle Functions. In T. Reiners & L. C. Wood (Eds.), *Gamification in Education and Business* (pp. 637–661). Cham: Springer.

Dillard, James Price, & Shen, L. (2005). On the nature of reactance and its role in persuasive health communication. *Communication Monographs*, *72*(2), 144–168.

Dittrich, M. (2020). *Patent No. DE10 2019 003 623.9*. München: Deutsches Patent- und Markenamt.

Dittrich, M., & Zepf, S. (2019). Exploring the Validity of Methods to Track Emotions Behind the Wheel. In H. Oinas-Kukkonen, K. T. Win, E. Karapanos, P. Karppinen, & E. Kyza (Eds.), *Proceedings of the PERSUASIVE 2019 Conference on Persuasive Technology, LNCS, vol. 11433* (pp. 115–127). Cham: Springer.

Dollard, J., Miller, N. E., Doob, L. W., Mowrer, O. H., & Sears, R. R. (1939). *Frustration and aggression*. New Haven: Yale University Press.

Doob, A. N., & Gross, A. E. (1968). Status of Frustrator as an Inhibitor of Horn-Honking Responses. *Journal of Social Psychology*, *76*(2), 213–218.

Ducheneaut, N., Don Wen, M. H., Yee, N., & Wadley, G. (2009). Body and mind: A study of avatar personalization in three virtual worlds. In *Proceedings of the CHI 2009 Conference on Human Factors in Computing Systems* (pp. 1151–1160). New York: ACM.

Duffy, B., & Joue, G. (2000). Intelligent robots: The question of embodiment. *Proceedings of BRAIN-MACHINE 2000 Workshop*, 20–29. Retrieved from http://www.csi.ucd.ie/prism/publications/desire/BrainMachine2000.pdf

Dula, C. S., & Ballard, M. E. (2003). Development and evaluation of a measure of dangerous, aggressive, negative emotional, and risky driving. *Journal of Applied Social Psychology*, *33*(2), 263–282.

Dula, C. S., & Geller, E. S. (2003). Risky, aggressive, or emotional driving: Addressing the need for consistent communication in research. *Journal of Safety Research*, *34*(5), 559–566.

Ehrenbrink, P., & Prezenski, S. (2017). Causes of Psychological Reactance in Human-Computer Interaction. In *Proceedings of the ECCE 2017 European Conference on Cognitive Ergonomics* (pp. 137–144). New York: ACM.

Ellison-Potter, P., Bell, P., & Deffenbacher, J. (2001). The Effects of Trait Driving Anger, Anonymity, and Aggressive Stimuli on Aggressive Driving Behavior. *Journal of Applied Social Psychology*, *31*(2), 431–443.

European Commission. (2018). Motorways 2018. Retrieved March 23, 2020, from https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/ersosynthesis2018-motorways.pdf

Eyben, F., Wöllmer, M., Poitschke, T., Schuller, B., Blaschke, C., Färber, B., & Nguyen-Thien, N. (2010). Emotion on the Road—Necessity, Acceptance, and Feasibility of Affective Computing in the Car. *Advances in Human-Computer Interaction*. https://doi.org/10.1155/2010/263593

FakhrHosseini, M., & Jeon, M. (2016). The Effects of Various Music on Angry Drivers' Subjective, Behavioral, and Physiological States. In *Proceedings of the Automotive'UI 2016 Conference on Automotive User Interfaces and Interactive Vehicular* (pp. 191–196). New York: ACM.

Feng, J., & Donmez, B. (2013). Design of Effective Feedback: Understanding Driver, Feedback, and Their Interaction. In *Proceedings of the International Driving Symposium 2013 on Human Factors in Driver Assessment, Training and Vehicle*

Design. https://doi.org/10.17077/drivingassessment.1519

Ferrara, J. (2013). Games for persuasion: Argumentation, procedurality, and the lie of gamification. *Games and Culture*, *8*(4), 289–304.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics* (4th ed.). London: Sage.

Fishbein, M. (1967). *Readings in Attitude Theory and Measurement*. New York, London, Sydney: John Wiley & Sons.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behaviour: An introduction to theory and research*. Boston: Addison-Wesley.

Fishbein, M., & Ajzen, I. (2010). *Predicting and Changing Behavior. The Reasoned Action Approach*. New York: Psychology Press.

Fogg, B. J. (1998). Persuasive computers: Perspectives and research directions. In *Proceedings of the CHI 1998 Conference on Human Factors in Computing Systems* (pp. 225–232). New York: ACM.

Fogg, B. J. (2003). *Persuasive technology: using computers to change what we think and do*. Burlington: Morgan Kaufmann Publishers.

Fogg, B. J., Cuellar, G., & Danielson, D. (2002). Motivating, influencing, and persuading users. In A. Sears & J. A. Jacko (Eds.), *Human-Computer Interaction. Fundamentals* (pp. 133–147). Boca Raton, London, New York: CRC Press.

Ford. (2016). 2017 Ford Fusion Hybrid. Retrieved February 7, 2020, from https://media.ford.com/content/fordmedia/fna/us/en/multimedia/album/2017/2017-ford-fusion-hybrid.html

Fourdesire. (2014). Plant Nanny. Retrieved from https://apps.apple.com/de/app/plant-nanny/id590216134

Franke, T., Attig, C., & Wessel, D. (2019). A Personal Resource for Technology Interaction: Development and Validation of the Affinity for Technology Interaction (ATI) Scale. *International Journal of Human-Computer Interaction*, *35*(6), 456–467.

Frankish, K. (2010). Dual-Process and Dual-System Theories of Reasoning. *Philosophy Compass*, *5*(10), 914–926.

Fredrickson, B. L., & Kahneman, D. (1993). Duration Neglect in Retrospective Evaluations of Affective Episodes. *Journal of Personality and Social Psychology*, *65*(1), 45–55.

Fröhlich, M., & Pieter, A. (2009). Cohen's Effektstärken als Mass der Bewertung von Praktischer Relevanz - Implikationen für die Praxis. *Schweizerische Zeitschrift Für Sportmedizin Und Sporttraumatologie*, *57*(4), 139–142.

Frude, N., & Jandrić, P. (2015). The intimate machine – 30 years on. *E-Learning and Digital Media*, *12*(3–4), 410–424.

Fullwood, C., Quinn, S., Kaye, L. K., & Redding, C. (2017). My virtual friend: A qualitative analysis of the attitudes and experiences of Smartphone users: Implications for Smartphone attachment. *Computers in Human Behavior*, *75*, 347–355.

Galovski, T. E., & Blanchard, E. B. (2002). The effectiveness of a brief psychological intervention on court-referred and self-referred aggressive drivers. *Behaviour Research and Therapy*, *40*(12), 1385–1402.

Gawronski, B., & Creighton, L. A. (2013). Dual Process Theories. In D. E. Carlston (Ed.), *The Oxford handbook of social cognition* (pp. 282–312). New York: Oxford University Press.

Gegenbauer, S., & Huang, E. M. (2012). Inspiring the design of longer-lived electronics through an understanding of personal attachment. In *Proceedings of the DIS 2012 Conference on Designing Interactive Systems* (pp. 635–644). New York: ACM.

Gkouskos, D., Pettersson, I., Karlsson, M., & Chen, F. (2015). Exploring User Experience in the Wild : Facets of the Modern Car. In A. Marcus (Ed.), *Proceedings of the DUXU 2015 Conference on Design, User Experience, and Usability: Interactive Experience Design, LNCS, vol. 9188* (pp. 450–461). Cham: Spinger.

Golan, G. J., & Day, A. G. (2008). The first-person effect and its behavioral consequences: A new trend in the twenty-five year history of third-person effect research. *Mass Communication and Society*, *11*(4), 539–556.

Görtz, M., Mandl, T., Arévalo, L., & Womser-Hacker, C. (2007). "Helen" – Embodiment in Automobile Speech User Interfaces. In T. Paul-Stueve (Ed.), *Workshopband Mensch und Computer 2017* (pp. 25–30). Weimar: Verlag der Bauhaus-Universität Weimar.

Gröning, P. (2020). The fast and the furi-ous: Research shows that own-ers of high-status cars are on a collision course with traffic. Retrieved March 8, 2020, from https://www.helsinki.fi/en/news/nordic-welfare-news/the-fast-and-the-furious-research-shows-that-owners-of-high-status-cars-are-on-a-collision-course-with-traffic

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology*, *2*(3), 271–299.

Gross, J. J., & Thompson, R. A. (2007). Emotion Regulation: Conceptual Foundations. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 3–24). New York: The Guilford Press.

Hall, J., Rus-Calafell, M., Omari-Asor, L., Ward, T., Emsley, R., Garety, P., & Craig, T. K. J. (2018). Assessing the subjective experience of participating in a clinical trial (AVATAR). *Psychiatry Research*, (263), 82–87.

Hamari, J., Koivisto, J., & Pakkanen, T. (2014). Do persuasive technologies persuade? - A review of empirical studies. In A. Spagnolli, L. Chittaro, & L. Gamberini (Eds.), *Proceedings of the PERSUASIVE 2014 Conference on Persuasive Technology, LNCS, vol. 8462* (pp. 118–136). Cham: Springer.

Harjumaa, M., & Oinas-Kukkonen, H. (2007). Persuasion Theories and IT Design. In Y. de Kort, W. IJsselsteijn, C. Midden, B. Eggen, & B. J. Fogg (Eds.), *Proceedings of the PERSUASIVE 2007 Conference on Persuasive Technology, LNCS, vol. 4744* (pp. 311–314). Berlin, Heidelberg: Springer.

Harris, P. B., Houston, J. M., Vazquez, J. A., Smither, J. A., Harms, A., Dahlke, J. A., & Sachau, D. A. (2014). The Prosocial and Aggressive Driving Inventory (PADI): A self-report measure of safe and unsafe driving behaviors. *Accident Analysis and Prevention*, *72*, 1–8.

Harvey, J., & Smedley, K. (2012). *Psychological therapy in prisons and other secure settings*. New York: Willan Publishing.

Hassenzahl, M., Burmester, M., & Koller, F. (2003). AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität. In G. Szwillus & J. Ziegler (Eds.), *Tagungsband Mensch und Computer 2013* (pp. 187–196). Stuttgart: Vieweg+Teubner.

Healey, J. (2011). Recording affect in the field: Towards methods and metrics for improving ground truth labels. In S. D'Mello, A. Graesser, B. Schuller, & J.-C. Martin (Eds.), *Proceedings of the ACII 2011 Conference on Affective Computing and Intelligent Interaction, LNCS, 6974* (pp. 107–116). Berlin, Heidelberg: Spinger.

Hernandez, J., McDuff, D., Benavides, X., Amores, J., Maes, P., & Picard, R. (2014). AutoEmotive: Bringing Empathy to the Driving Experience to Manage Stress. In *Companion Publication of the DIS 2014 Conference on Designing Interactive Systems* (pp. 53–56). New York: ACM.

Hertlein, K. M., & Twist, M. L. C. (2018). Attachment to Technology: The Missing Link. *Journal of Couple & Relationship Therapy*, *17*(1), 2–6.

Holtzblatt, K., & Beyer, H. R. (1993). Making Customer-Centered Design Work for Teams. Association for Computing Machinery. *Communications of the ACM*, *36*(10), 92–103.

Horberry, T., Anderson, J., Regan, M. A., Triggs, T. J., & Brown, J. (2006). Driver distraction: The effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance. *Accident Analysis and Prevention*, *38*(1), 185–191.

Houston, J. M., Harris, P. B., & Norman, M. (2003). The Aggressive Driving Behavior Scale: Developing a self-report measure of unsafe driving practices. *North American Journal of Psychology*, *5*(2), 269–278.

International Organization for Standardization. (2019). ISO 9241-210:2019 Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems. Retrieved from https://www.iso.org/obp/ui/#iso:std:iso:9241:-210:ed-2:v1:en

Jalonen, H. (2012). The Uncertainty of Innovation: A Systematic Review of the Literature. *Journal of Management Research*, *4*(1), 1–53.

Jensen, J. D., & Hurley, R. J. (2005). Third-person effects and the environment: Social distance, social desirability, and presumed behavior. *Journal of Communication*, *55*(2), 242–256.

Jeon, M., & Walker, B. N. (2011). What to detect? Analyzing factor structures of affect in driving contexts for an emotion detection and regulation system. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting 2011* (pp. 1889–1893). Los Angeles: Sage.

Jonsson, I. M., Nass, C., Endo, J., Reaves, B., Harris, H., Le Ta, J., ... Knapp, S. (2004). Don't blame me i am only the driver: Impact of blame attribution on attitudes and attention to driving task. In *Extended Abstracts of the CHI 2004 Conference on Human Factors in Computing Systems* (pp. 1219–1222). New York: ACM.

Justel, D., Vidal, R., Arriaga, E., Franco, V., & Val-Jauregi, E. (2007). Evaluation method for selecting innovative product concepts with greater potential marketing success. In *Proceedings of the ICED 2007 International Conference on Engineering Design*. Retrieved from https://www.designsociety.org/publication/25508/Evaluation+Method+for+Selecting+Innovative+Product+Concepts+With+Greater+Potential+Marketing+Success

Karahalios, A., Baglietto, L., Carlin, J. B., English, D. R., & Simpson, J. A. (2012). A review of the reporting and handling of missing data in cohort studies with repeated assessment of exposure measures. *BMC Medical Research Methodology*, *12*(96), 1–10.

Kern, E. (2013, November 15). Daten-Überwachung: Die erste vom Fahrverhalten abhängige Versicherung. *Die Welt.* Retrieved from https://www.welt.de/finanzen/versicherungen/article121912643/Die-erste-vom-Fahrverhalten-abhaengige-Versicherung.html

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine*, *15*(2), 155–163.

Krahé, B., & Fenske, I. (2002). Predicting aggressive driving behavior: The role of macho personality, age, and power of car. *Aggressive Behavior*, *28*(1), 21–29.

Krahmer, E., & Swerts, M. (2009). Audiovisual Prosody-Introduction to the Special Issue. *Language and Speech*, *52*(2–3), 129–133.

Krebs, P., Prochaska, J. O., & Rossi, J. S. (2010). Defining what works in Tailoring: A Meta-analysis of Computertailored Interventions for Health. *Prevention Medicine*, *51*(3–4), 214–221.

Lally, P., van Jaarsveld, C. H. M., Potts, H. W. W., & Wardle, J. (2010). How are habits formed: Modelling habit formation in the real world. *European Journal of Social Psychology*, *40*(6), 998–1009.

Laugwitz, B., Held, T., & Schrepp, M. (2008). Construction and evaluation of a user experience questionnaire. In A. Holzinger (Ed.), *Proceedings of the USAB 2008 Conference on HCI and Usability for Education and Work, LNCS, vol. 5298* (pp. 63–76). Berlin, Heidelberg: Springer.

Laurans, G. (2011). *On the moment-to-moment measurement of emotion during person-product interaction (doctoral dissertation).* Université Nancy, DESS Psychologie du travail et nouvelles technologies, Nancy.

Lawton, L. (2017). Taken by the Tamagotchi: How a Toy Changed the Perspective on Mobile Technology. *The IJournal*, *2*(2), 1–9.

Lew, L., Nguyen, T., Messing, S., & Westwood, S. (2011). Of course I wouldn't do that in real life. In *Extended Abstracts of the CHI 2011 Conference on Human Factors in Computing Systems* (pp. 419–429). New York: ACM.

Libakova, N. M., & Sertakova, E. A. (2015). The Method of Expert Interview as an Effective Research Procedure of Studying the Indigenous Peoples of the North. *Humanities & Social Sciences*, *8*(1), 114–129.

Llagostera, E. (2012). On gamification and persuasion. In *Proceedings of the SB Games 2012 Conference on Games & Digital Entertainment.* Retrieved from http://www.sbgames.org/sbgames2012/proceedings/papers/gamesforchange/g4c-02.pdf

Lobe, A. (2020, March 2). Verkehrssicherheit: Der unsichtbare Polizist fährt mit. *Zeit.* Retrieved from https://www.zeit.de/kultur/2020-02/verkehrssicherheit-automatisierung-kuenstliche-intelligenz-auto-strafvollzug/komplettansicht

Lönnqvist, J. E., Ilmarinen, V. J., & Leikas, S. (2019). Not only assholes drive Mercedes. Besides disagreeable men, also conscientious people drive high-status cars. *International Journal of Psychology*, *54*(6), 1–5.

Lutfi Bin Dolhalit, M., Nur Binti Abdul Salam, S., & Bin Abdul Mutalib, A. (2016). A Review on Persuasive Technology (PT) Strategy in Awareness Study. *Indian Journal of Science and Technology*, *9*(34), 1–6.

Maguire, M. (2001). Methods to support human-centred design. *International Journal of Human Computer Studies*, *55*(4), 587–634.

Mäkinen, T., Zaidel, D. M., Andersson, G., Biecheler-Fretel, M.-B., Christ, R., Cauzard, J.-P., ... Vaa, T. (2003). *Traffic enforcement in Europe: effects, measures, needs and future*. Espoo: Technical Research Centre of Finland.

Marshall, D. C., Lee, J. D., & Austria, P. A. (2007). Alerts for in-vehicle information systems: Annoyance, urgency, and appropriateness. *Human Factors*, *49*(1), 145–157.

Martelaro, N., & Ju, W. (2017). WoZ Way: Enabling real-time remote interaction prototyping & observation in on-road vehicles. In *Proceedings of the CSCW 2017 Conference on Computer Supported Cooperative Work and Social Computing* (pp. 21–24). New York: ACM.

Matthews, J., Win, K. T., Oinas-Kukkonen, H., & Freeman, M. (2016). Persuasive Technology in Mobile Applications Promoting Physical Activity: a Systematic Review. *Journal of Medical Systems*, *40*(72), 1–13.

McCartt, A. T., Leaf, W. A., Witkowski, T. L., & Solomon, M. G. (2001). *Evaluation of the Aggression Suppression Program*. Washington, D.C.: National Highway Traffic Safety Administration.

McConnell, J. V. (1990). Negative reinforcement and positive punishment. *Teaching of Psychology*, *17*(4), 247–249.

Mercedes-Benz. (2019). Mercedes-Benz Versuchsteilnahme. Retrieved February 10, 2020, from https://www.mercedes-benz-stuttgart.de/de/desktop/passenger-cars/actions/offers-new-cars/versuchsteilnahme-mercedes-benz.html

Mercedes-Benz. (2020). Effizienterer Fahrstil: Die ECO-Anzeige. Retrieved January 14, 2020, from https://www.mercedes-benz.de/passengercars/mercedes-benz-cars/wltp/wltp/efficiency-economy/economic-driving/eco-display.html

Meschtscherjakov, A., Wilfinger, D., Scherndl, T., & Tscheligi, M. (2009). Acceptance of future persuasive in-car interfaces towards a more economic driving behaviour. In *Proceedings of the Automotive'UI 2009 Conference on Automotive User Interfaces and Interactive Vehicular* (pp. 81–88). New York: ACM.

Mesken, J., Hagenzieker, M. P., Rothengatter, T., & de Waard, D. (2007). Frequency, determinants, and consequences of different drivers' emotions: An on-the-road study using self-reports, (observed) behaviour, and physiology. *Transportation Research Part F: Traffic Psychology and Behaviour*, *10*(6), 458–475.

Miller, G. R. (2013). On being persuaded: Some basic distinctions. In J P Dillard & L. Shen (Eds.), *The SAGE handbook of persuasion: Developments in theory and practice* (pp. 70–82). Thousand Oaks: Sage.

Miron-Spektor, E., & Rafaeli, A. (2009). The effects of anger in the workplace: When, where, and why observing anger enhances or hinders performance. *Research in Personnel and Human Resources Management*, *28*, 153–178.

Mugge, R., Schoormans, J. P. L., & Schifferstein, H. N. J. (2009). Emotional bonding with personalised products. *Journal of Engineering Design*, *20*(5), 467–476.

Murdock, B. B. (1962). The serial position effect of free recall. *Journal of Experimental Psychology*, *64*(5), 482–488.

Nakagawa, Y., Park, K., Ueda, H., & Ono, H. (2017). Being Watched over by a Conversation Robot Enhances Safety in Simulated Driving. *Social Design Engineering Series*, *16*, 1–33.

Nass, C., Jonsson, I.-M., Harris, H., Reaves, B., Endo, J., Brave, S., & Takayama, L. (2005). Improving automotive safety by pairing driver emotion and car voice emotion. In *Extended Abstracts of the CHI 2005 Conference on Human Factors in Computing Systems* (pp. 1973–1976). New York: ACM.

National Highway Traffic Safety Administration. (2016). *Visual-Manual NHTSA Driver Distraction Guidelines for Portable and Aftermarket Devices.* Washington D.C.: National Highway Traffic Safety Administration.

Neuman, J. H., & Baron, R. A. (1998). Workplace violence and workplace aggression: Evidence concerning specific forms, potential causes, and preferred targets. *Journal of Management*, *24*(3), 391–419.

Nichols, A. L., & Maner, J. K. (2008). The good-subject effect: Investigating participant demand characteristics. *Journal of General Psychology*, *135*(2), 151–166.

Niven, K., Totterdell, P., & Holman, D. (2009). A Classification of Controlled Interpersonal Affect Regulation Strategies. *Emotion*, *9*(4), 498–509.

O'Sullivan, D., & Dooley, L. (2008). *Applying Innovation.* Los Angeles: Sage.

Odom, W., Pierce, J., Stolterman, E., & Blevis, E. (2009). Understanding why we preserve some things and discard others in the context of interaction design. In *Proceedings of the CHI 2009 Conference on Human Factors in Computing Systems* (pp. 1053–1062). New York: ACM.

Oinas-Kukkonen, H., & Harjumaa, M. (2008). Towards deeper understanding of persuasion in software and information systems. In *Proceedings of the ACHI 2008 International Conference on Advances in Computer-Human Interaction* (pp. 200–205). New York: ACM.

Oinas-Kukkonen, H., & Harjumaa, M. (2009). Persuasive Systems Design: Key Issues, Process Model, and System Features. *Communications of the Association for Information Systems*, *24*(28), 486–500.

Orji, R., & Moffatt, K. (2018). Persuasive technology for health and wellness: State-of-the-art and emerging trends. *Health Informatics Journal*, *24*(1), 66–91.

Ovington, L. A., Saliba, A. J., Moran, C. C., Goldring, J., & MacDonald, J. B. (2018). Do People Really Have Insights in the Shower? The When, Where and Who of the Aha! Moment. *Journal of Creative Behavior*, *52*(1), 21–34.

Özkan, T., & Lajunen, T. (2005). A new addition to DBQ: Positive driver behaviours scale. *Transportation Research Part F: Traffic Psychology and Behaviour*, *8*(4–5), 355–368.

Paek, H.-J., Hove, T., Ju Jeong, H., & Kim, M. (2011). Peer or expert? The persuasive impact of YouTube public service announcement producers. *International Journal of Advertising*, *30*(1), 161–188.

Paraschivoiu, I., Meschtscherjakov, A., Gärtner, M., & Sypniewski, J. (2019). Persuading the Driver: A Framework for Persuasive Interface Design in the Automotive Domain. In H. Oinas-Kukkonen, K. W. Than, E. Karapanos, P. Karppinen, & E. Kyza (Eds.), *Proceedings of the PERSUASIVE 2019 Conference on Persuasive Technology, LNCS, vol. 11433* (pp. 128–140). Cham: Springer.

Paredes, P. E., Zhou, Y., Al-Huda Hamdan, N., Balters, S., Murnane, E., & Ju, W. (2018). Just Breathe: In-Car Interventions for Guided Slow Breathing. In *Proceedings of the ACM Conference on Interactive, Mobile, Wearable and Ubiquitous Technologies* (pp. 28:1-28:23). New York: ACM.

Parkinson, B. (2008). Emotions in direct and remote social interaction: Getting through the spaces between us. *Computers in Human Behavior*, *24*(4), 1510–1529.

Pauzie, A. (2009). A method to assess the driver mental workload: the Driving Activity

Load Index (DALI). *IET Intelligent Transport Systems*, *2*(4), 315–322.

Peter, C., & Herbon, A. (2006). Emotion representation and physiology assignments in digital systems. *Interacting with Computers*, *18*(2), 139–170.

Petty, R. E., & Cacioppo, J. T. (1986). The elaboration likelihood model of persuasion. In L. Berkowitz (Ed.), *Advances in Experimental Social Psychology* (pp. 123–205). New York: Academic Press.

Pfeifer, R., & Iida, F. (2003). Embodied Artificial Intelligence: Trends and Challenges. In F. Iida, R. Pfeifer, L. Steels, & Y. Kuniyoshi (Eds.), *Embodied Artificial Intelligence, LNCS, vol. 3139* (pp. 1–29). Berlin: Springer.

Poels, K., de Kort, Y. A. W., & IJsselsteijn, W. A. (2013). *Game Experience Questionnaire: development of a self-report measure to assess the psychological impact of digital games.* Eindhoven: Technische Universiteit Eindhoven.

Pogrow, S. (2019). How Effect Size (Practical Significance) Misleads Clinical Practice: The Case for Switching to Practical Benefit to Assess Applied Research Findings. *American Statistician*, *73*(1), 223–234.

Popuşoi, S., & Holman, A. (2016). Driving anger and aggressive tendency: The moderating role of emotion regulation strategy. *Bulletin of the Transilvania University of Braşov*, *9*(2), 153–164.

Rauschnabel, P. A., & Ahuvia, A. C. (2014). You're so lovable: Anthropomorphism and brand love. *Journal of Brand Management*, *21*(5), 372–395.

Reeves, B., & Nass, C. (1996). *Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places.* Cambridge: Cambridge University Press.

Renault. (2019). DRIVING ECO. Retrieved February 7, 2020, from https://at.e-guide.renault.com/deu/R-LINK2/DRIVING-ECO2

Retting, R. A., & Greene, M. A. (1997). Influence of traffic signal timing on red-light running and potential vehicle conflicts at urban intersections. *Transportation Research Record*, *1595*(1), 1–7.

Rew, M., & Ferns, T. (2014). A balanced approach to dealing with violence and aggression at work. *British Journal of Nursing*, *14*(4), 227–232.

Rice, M., Koh, R., Liu, Q., He, Q., Wan, M., Yeo, V., … Tan, W. P. (2013). Comparing Avatar Game Representation Preferences across Three Age Groups. In *Extended Abstracts of the CHI 2013 Conference on Human Factors in Computing Systems* (pp. 1161–1166). New York: ACM.

Richert, A., Müller, S., Schröder, S., & Jeschke, S. (2018). Anthropomorphism in social robotics: empirical results on human–robot interaction in hybrid production workplaces. *AI and Society*, *33*(3), 413–424.

Riener, A. (2012). Subliminal persuasion and its potential for driver behavior adaptation. *IEEE Transactions on Intelligent Transportation Systems*, *13*(1), 71–80.

Rottenberg, J., & Gross, J. J. (2007). Emotion and Emotion Regulation: A Map for Psychotherapy Researchers. *Clinical Psychology: Science and Practice*, *14*(4), 323–328.

Ruiz, M. C., & Hanin, Y. L. (2004). Athletes' self perceptions of optimal states in karate: an application of the izof model. *Revista de Psicologia Del Deporte*, *13*(2), 229–244.

Scherer, K. R. (2005). What are emotions? and how can they be measured? *Social Science Information*, *44*(4), 695–729.

Schlatz, I. (2014). Alles über Bandai Tamagotchis. Retrieved March 26, 2020, from http://www.tamagotchi.de/index2.html

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review*, *84*(1), 1–66.

Schumpeter, J. A. (1947). The Creative Response in Economic History. *The Journal of Economic History*, *7*(2), 149–159.

Scotney, V., Weissmeyer, S., & Gabora, L. (2014). Cross-Domain Influences on Creative Processes and Products. In C. Kalish, M. Rau, J. Zhu, & T. Rogers (Eds.), *Proceedings of the CogSci 2014 Annual Meeting of the Cognitive Science Society* (pp. 2455–2460). Austin: Cognitive Science Society.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. *Psychological Review*, *84*(2), 127–190.

Shinar, D. (1998). Aggressive driving: The contribution of the drivers and the situation. *Transportation Research Part F: Traffic Psychology and Behaviour*, *1*(2), 137–160.

Simons, H. W., & Jones, J. G. (2011). *Persuasion in Society* (2nd ed.). New York: Routledge.

Skinner, B. F. (1963). Operant behavior. *American Psychologist*, *18*(8), 503–515.

Soroa, A., Wollstädterb, S., & Rakotonirainya, A. (2014). Advanced in-vehicle applications to mitigate driver aggression. In N. Stanton, S. Landry, G. di Bucchianico, & A. Vallicelli (Eds.), *Advances in Human Aspects of Transportation: Part II* (pp. 348–345). n.p.: AHFE Conference.

Spahn, A. (2012). And Lead Us (Not) into Persuasion...? Persuasive Technology and the Ethics of Communication. *Science and Engineering Ethics*, *18*(4), 633–650.

Spiekermann, S., & Pallas, F. (2006). Technology paternalism - Wider implications of ubiquitous computing. *Poiesis Und Praxis*, *4*(1), 6–18.

Statistisches Bundesamt. (2019a). Fehlverhalten der Fahrzeugführer bei Unfällen mit Personenschaden. Retrieved March 4, 2020, from https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Verkehrsunfaelle/Tabellen/fehlverhalten-fahrzeugfuehrer.html

Statistisches Bundesamt. (2019b). Verkehrsverstöße in Deutschland nach Deliktgruppen. Retrieved March 4, 2020, from https://sta.cir-mcs.e.corpintra.net/statistik/daten/studie/5397/umfrage/verkehrsverstoesse-nach-ausgewaehlten-deliktgruppen/

Statistisches Bundesamt. (2020a). Anzahl der Personen in Deutschland, die einen PKW-Führerschein besitzen, von 2016 bis 2019. Retrieved from https://de.statista.com/statistik/daten/studie/172091/umfrage/besitz-eines-pkw-fuehrerscheins/

Statistisches Bundesamt. (2020b). Durchschnittliche jährliche Fahrleistung des PKW in Deutschland. Retrieved February 25, 2020, from https://de.statista.com/statistik/daten/studie/183003/umfrage/pkw---gefahrene-kilometer-pro-jahr/

Statistisches Bundesamt. (2020c). Gesamte Staulänge auf Autobahnen in Deutschland in den Jahren 2002 bis 2019. Retrieved March 4, 2020, from https://de.statista.com/statistik/daten/studie/200201/umfrage/gesamte-staulaenge-auf-autobahnen-in-deutschland/

Statistisches Bundesamt. (2020d). Share of drivers who primarily drive a Mercedes-

Benz in the United States in 2018, by age. Retrieved March 26, 2020, from https://www.statista.com/statistics/227750/people-living-in-households-that-own-a-new-mercedes-usa/

Staubach, M., Kassner, A., Fricke, N., Schießl, C., Brockmann, M., & Kuck, D. (2012). Driver reactions on ecological driver feedback via different HMI modalities. In *Proceedings on the ITS 2012 Intelligent Transport Systems World Congress*. Retrieved from https://elib.dlr.de/78202/

Steen, M. (2011). Tensions in human-centred design. *CoDesign*, *7*(1), 45–60.

Steindl, C., Jonas, E., Sittenthaler, S., Traut-Mattausch, E., & Greenberg, J. (2015). Understanding psychological reactance: New developments and findings. *Zeitschrift Für Psychologie*, *223*(4), 205–214.

Stuster, J. (2004). *Aggressive Driving Enforcement: Evaluation of Two Demonstration Programs*. Washington, D.C.: National Highway Traffic Safety Administration.

Taubman-Ben-Ari, O., Mikulincer, M., & Gillath, O. (2004). The multidimensional driving style inventory - Scale construct and validation. *Accident Analysis and Prevention*, *36*(3), 323–332.

Taylor, A., Atkins, R., Kumar, R., Adams, D., & Glover, V. (2005). A new mother-to-infant bonding scale: Links with early maternal mood. *Archives of Women's Mental Health*, *8*(1), 45–51.

Thorsteinsson, G., & Page, T. (2014). User attachment to smartphones and design guidelines. *International Journal of Mobile Learning and Organisation*, *8*(3), 201–215.

Tondello, G. F., Wehbe, R. R., Diamond, L., Busch, M., Marczewski, A., & Nacke, L. E. (2016). The gamification user types Hexad scale. In *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play* (pp. 229–243). New York: ACM.

Turkle, S., Taggart, W., Kidd, C. D., & Dasté, O. (2006). Relational artifacts with children and elders: the complexities of cybercompanionship. *Connection Science*, *18*(4), 347–361.

Turner, C. W., Layton, J. F., & Simons, L. S. (1975). Naturalistic studies of aggressive behavior: Aggressive stimuli, victim visibility, and horn honking. *Journal of Personality and Social Psychology*, *31*(6), 1098–1107.

Uludag, O. (2014). Fair and Square: How does Perceptions of Fairness is Associated to Aggression? *Procedia - Social and Behavioral Sciences*, *143*, 504–508.

Underwood, G., Chapman, P., Wright, S., & Crundall, D. (1999). Anger while driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *2*(1), 55–68.

Vincent, J. (2005). Emotional Attachment to Mobile Phones: An Extraordinary Relationship. In L. Hamill & A. Lasen (Eds.), *Mobile World. Past, Present and Future* (pp. 1689-95–104). London: Springer.

Wang, C., Terken, J., Yu, B., & Hu, J. (2015). Reducing driving violations by receiving feedback from other drivers. In *Adjunct Proceedings of the Automotive'UI 2015 Conference on Automotive User Interfaces and Interactive Vehicular* (pp. 62–67). New York: ACM.

Webb, K. (2019). The best-selling video game of every year, from 1995 to 2019. Retrieved May 12, 2020, from https://www.businessinsider.com/best-selling-video-game-every-year-2018-11?r=DE&IR=T#2019-call-of-duty-modern-warfare-playstation-4-xbox-one-pc-25

Wells, J. D., Campbell, D. E., Valacich, J. S., & Featherman, M. (2010). The Effect of Perceived Novelty on the Adoption of Information Technology Innovations: A Risk/Reward Perspective. *Decision Sciences*, *41*(4), 813–843.

Werbach, K. (2015). (Re)Defining Gamification: A Process Approach. In A. Spagnolli, L. Chittaro, & L. Gamberini (Eds.), *Proceedings of the PERSUASIVE 2015 Conference on Persuasive Technology, LNCS, vol. 9072* (pp. 266–272). Cham: Springer.

Wickens, C. M., Mann, R. E., & Wiesenthal, D. L. (2013). Addressing Driver Aggression: Contributions From Psychological Science. *Current Directions in Psychological Science*, *22*(5), 386–391.

Wiese, E., Shaw, T., Lofaro, D., & Baldwin, C. (2017). Designing artificial agents as social companions. In *Proceedings of the Human Factors and Ergonomics Society 2017 Annual Meeting* (pp. 1604–1608). Los Angeles: Sage.

Wijngaarden, Y., Hitters, E., & Bhansing, P. V. (2019). 'Innovation is a dirty word': contesting innovation in the creative industries. *International Journal of Cultural Policy*, *25*(3), 392–405.

Wilson, G. T., Bhamra, T., & Lilley, D. (2015). The considerations and limitations of feedback as a strategy for behaviour change. *International Journal of Sustainable Engineering*, *8*(3), 186–195.

Yagana, S. (2016, January 18). The Surprising Link Between Road Rage And How Long You'll Live. *Huffington Post.* Retrieved from https://www.huffpost.com/entry/road-rage-can-pose-long-term-health-risks-study-says_n_569d0585e4b0b4eb759f186b

Yoon, G., & Vargas, P. T. (2016). See Myself through My Avatar: Evidence from East Asia and North America for Acculturated Effects on Virtual Representation Preference. *Asiascape: Digital Asia*, *3*(1–2), 79–96.

Yuan, L. (Ivy), & Dennis, A. R. (2019). Acting Like Humans? Anthropomorphism and Consumer's Willingness to Pay in Electronic Commerce. *Journal of Management Information Systems*, *36*(2), 450–477.

Zarkadakis, G. (2016). *In Our Own Image: Savior or Destroyer? the History and Future of Artificial Intelligence.* New York: Pegasus Books.

Zeit. (2020, February 14). Geschwindigkeitsbegrenzung: Kein Tempolimit auf Autobahnen. *Zeit.* Retrieved from https://www.zeit.de/mobilitaet/2020-02/tempolimit-geschwindigkeitsbegrenzung-autobahn-verkehrsregeln-radfahrer-bundesrat

Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in HCI. In *Proceedings of the CHI 2007 Conference on Human Factors in Computing Systems* (pp. 493–502). New York: ACM.

APPENDIX

A.1 Appendix Chapter III

Appendix 1.1. Interview guide of the preliminary study.

User Experience & Acceptance (RD/RIF) DAIMLER

Hallo, mein Name ist X von der Daimler AG. Darf ich Ihnen kurz ein paar Fragen zum Thema „Emotionen beim Fahren" stellen? Es dauert nicht länger als 2 bis 3 Minuten…

Interviewer:	Datum, Uhrzeit:	☐ Männlich ☐ Weiblich	**Nicht fragen, falls möglich schätzen:** ☐ < 35 ☐ 35-55 ☐ > 55

1. Fahrtbeschreibung (gerade absolvierte Fahrt):

Fahrtbeginn (Uhrzeit)	Dauer (min)	Verzögerung (min)	Strecke (km)	Fahrzeug (Marke, Modell, Baujahr)

2. *Wenn Sie an Ihre **heutige Fahrt hierher** denken: Haben Sie dabei insgesamt ein negatives oder ein positives Gefühl? Welches Gefühl könnte die Fahrt am besten beschreiben? (Falls neutral bitte notieren, aber nicht explizit anbieten)*

3. *Gab es bei dieser Fahrt etwas, das Sie erfreut bzw. positiv gestimmt hat? (Fahrsituation, „externe" Gedanken)*

4. *Gab es bei dieser Fahrt etwas, das Sie verärgert bzw. negativ gestimmt hat? (Fahrsituation, „externe" Gedanken)*

Appendix 1.2. Description of types of negative emotional triggers while driving.

Type	Description
Vehicle	Functionality and user experience issues of the car and its systems
Navigation	Functional errors of the navigation system
Driving speed	Traffic management requiring a decrease in velocity
Arrival	Deviations of the arrival time
Interaction with non-motorized road users	Illegal and illegitimate actions of pedestrians and cyclists directed at oneself, others, or the environment
Interactions with motorized road users	Illegal and illegitimate actions of drivers directed at oneself, others, or the environment
Orientation	Uncertainty about the current location
Entertainment	Referring to the content of audio media
Traffic volume	General intensity of traffic and congestion
Driving environment	Material aspects (e.g., speed camera), atmospheric aspects (e.g., bad weather), temporal aspects (e.g., Monday morning), and situational aspects (e.g., traffic accident) in and around the car.
Parking	Incidents occurring in parking areas and conditions of the parking space
Personal issues	Conditions caused by external circumstances and cognition not related to the current driving situation.
Traffic light	Incidents occurring at a traffic light or situations associated with the state of a traffic light
Road conditions	Quality of the road surface and construction of the road system
Own driving behavior	Driving errors of the driver

Appendix 1.3. Test route of the naturalistic driving study.

A.2 Appendix Chapter IV

Appendix 2.1. Job descriptions and professional experience in years of the expert sample.

Job description	Experience in years
(Psycho-)therapy	
Psychologist, head of the social-therapeutic department of a youth correctional institution	16
Psychologist, own traffic-psychological practice	22
Psychologist, own traffic-psychological practice	9
Psychologist, own psychotherapeutic practice	15
Alternative practitioner, own psychotherapeutic practice for children and adolescents	3
Working environments	
Personal coach for local government personnel	14
De-escalation trainer in healthcare	30
De-escalation trainer at schools	20
Physicist, participating in a Mars simulation	1
Traffic research	
Psychologist at a traffic research institute	19
Human factors researcher at an aeronautics research institute	5
Offenders work and forensic psychology	
Psychologist, self-employed consultant for violence prevention and management in public contexts	12
Educationalist at a psychotherapeutic practice for violent children and adolescents	20
Educationalist at an institute for violent children and adolescents	4
Sports	
Karate coach	26

Appendix 2.2. Interview guide of the expert interviews.

Experteninterview

Datum, Uhrzeit (Pn.-Nr.: JJMMTT_HHMM)	
Interview	
Protokoll	
Geschlecht Experte	☐ weiblich ☐ männlich

Einleitung

- Doktorarbeit zum Thema Aggression beim Autofahren und was man dagegen tun kann
- Wichtig heute:
  1. Es geht **nicht spezifisch um den Verkehrskontext**, sondern um **Ihre Erfahrungen und Ihre Arbeitspraxis.**

     Mich interessiert, wie in unterschiedlichen Anwendungsfeldern an das dem Thema Emotions- und Aggressionsregulation herangegangen wird, z.B. in der Psychotherapie, beim Sport, in der Kindererziehung.
  2. Zentrale Fragestellung: Welche Methoden werden in der Praxis eingesetzt, um Aggression **schnell und effektiv** zu regulieren?
  3. **Natürlich sollen Sie mir an dieser Stelle keine Details erzählen, die Rückschlüsse auf involvierte Personen zulassen.**

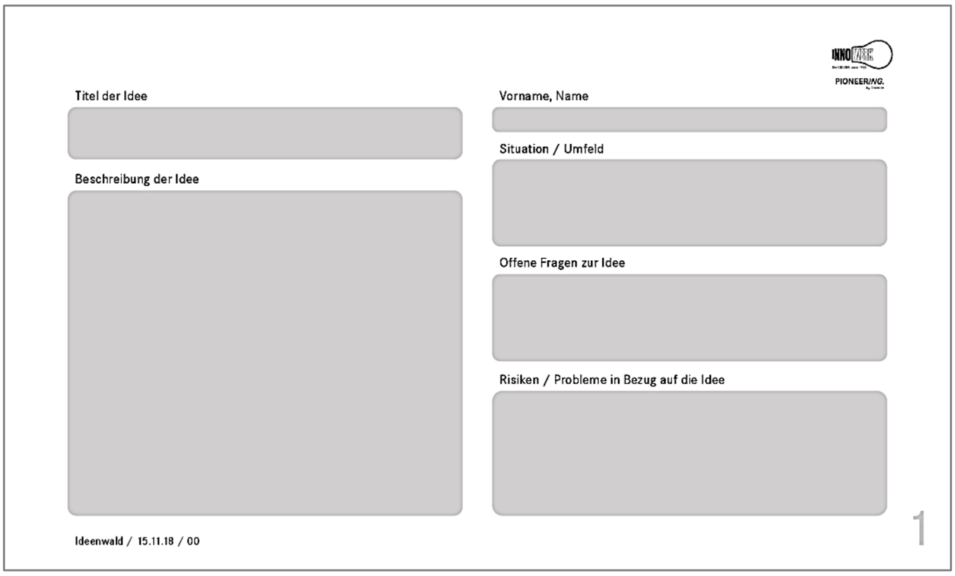
Berufliches Selbstverständnis	
(1)	**Tätigkeitsbeschreibung**
(2)	**Berufserfahrung zu (1) in Jahren:** ________________
(3)	**Berührungspunkte/Fallbeispiele zum Thema „Aggression" in der praktischen Arbeit**
Aggressions-Typen und Ursachen	
(4)	**Typen** ☐ Verlauf ☐ Häufigkeit ☐ Ausleben ☐ Warnzeichen
(5)	**Externe Auslöser** ☐ Situativ ☐ Interpersonal
(6)	**Dispositionelle Einflüsse**
(7)	**Weitere Einflüsse** ☐ Kultur ☐ Durchsetzungsfähigkeit
OPTIONAL: Entstehung von Aggression	
(8)	**Prozess/Modell Entstehung von Aggression**
(9)	**Zusammenhang Frustration, Wut und Aggression (Frustrations-Aggressions-Hypothese)**
Gesunde Beziehung	
(10)	**Definition „gesunde Beziehung" im Rahmen der Therapie/Training/Coaching**
(11)	**Rolle der Beziehung für erfolgreiches Arbeiten**
(12)	**Beziehungsaufbau**
Fallbeispiel	
💬	*Bitte denken Sie nun an einen Fall bzw. eine Person, der bzw. die Ihnen beim Thema Wut als erstes in den Sinn kommt.*
(13)	**Beschreibung und Besonderheiten**
(14)	**Herangehensweise und Behandlungsplanung** ☐ Relevante Informationen/Faktoren/Erfahrungen auf die man sich im Vorfeld bezieht ☐ Dauer und Frequenz der Behandlung ☐ Behandlungsstrategie (z.B. psychotherapeutisches Verfahren)

Seite **2** von **3**

Interventionen	
💬	*Ich interessiere mich vor allem für akut wirksame Maßnahmen die eine aggressive Person schnell beruhigen können.* *Denken Sie dazu ggf. noch einmal an den eben von Ihnen beschriebenen Fall…*
(15)	**Mit Anwesenheit Therapeut/Trainer etc.** ☐ Gestaltung der Umgebung ☐ Konkrete Interventionen ☐ Verbales Verhalten („richtige Ansprache“) ☐ Nonverbales Verhalten ☐ Reaktanz
(16)	**Selbsthilfe im Alltag** ☐ Positive und negative Umgebungen ☐ Konkrete Interventionen zur Selbsthilfe
Interventionen im Fahrzeug	
💬	*Während der Autofahrt gibt es Ereignisse, die Aggression auslösen können, z.B. Stau, rote Ampeln, Schleicher oder Drängler. Stellen Sie sich nun vor der von Ihnen beschrieben Fall steigt in ein Fahrzeug ein…*
(17)	**Ausleben von Aggression beim Autofahren**
(18)	**Der Beifahrer als Therapeut** ☐ Konkrete Interventionen, um Aggression des Betroffenen als Außenstehender zu regulieren
(19)	**Selbsthilfe im Fahrzeug** ☐ Konkrete Interventionen zur Selbsthilfe
Offene Punkte und Feedback	

A.3 Appendix Chapter V

Appendix 3.1. One-pagers filled in by the participants of the ideation workshops.



Titel der Idee

Vorname, Name

Situation / Umfeld

Beschreibung der Idee

Offene Fragen zur Idee

Risiken / Probleme in Bezug auf die Idee

Ideenwald / 15.11.18 / 00

1

Appendix 3.2. Evaluation sheets filled in by the participants of the ideation workshops.

Bewertungsskala	sehr niedrig	niedrig	weder noch	hoch	sehr hoch
	1	2	3	4	5

Nr.	Attraktivität	Nützlichkeit	Neuheit	Umsetzbarkeit	Notizen
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					

23.11.2018 – Ideenwald

DAIMLER

A.4 Appendix Chapter VI

Appendix 4.1. Screenshots of the online survey.

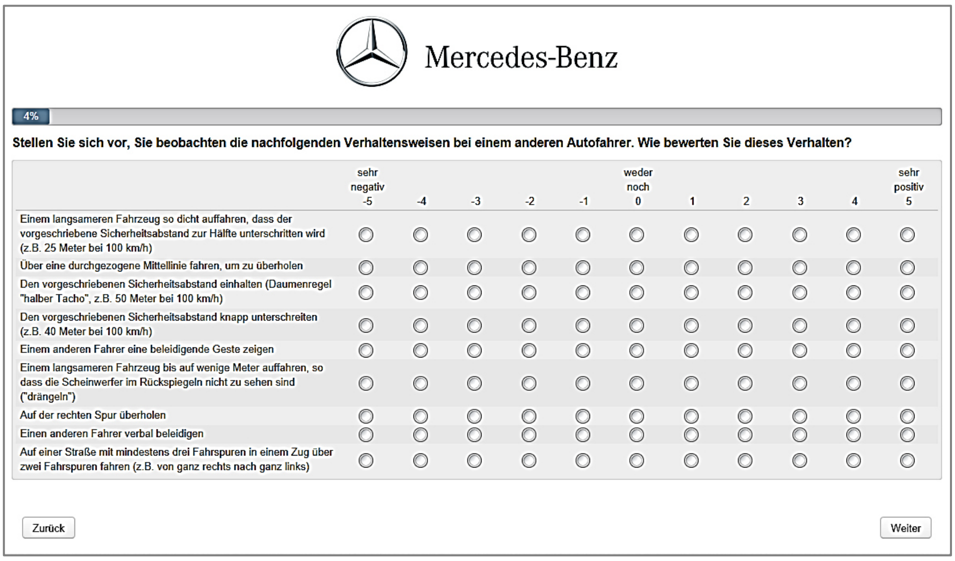
Mercedes-Benz

2%

Nachfolgend werden Ihnen verschiedene Fahrverhaltensweisen vorgestellt.

Nehmen Sie sich zunächst eine Minute Zeit und überlegen Sie, **welche Verhaltensweisen Sie bei anderen Autofahrern besonders gut oder schlecht finden**...

Weiter



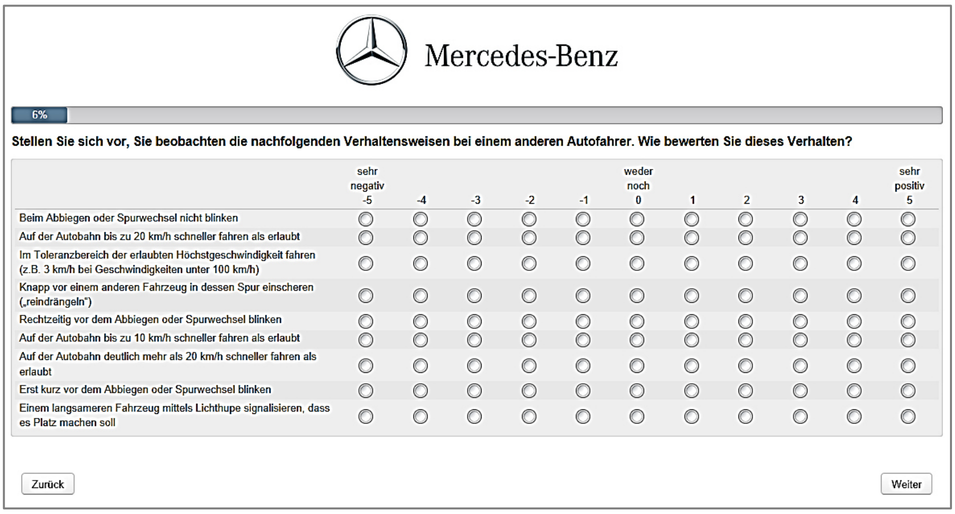
Mercedes-Benz

4%

Stellen Sie sich vor, Sie beobachten die nachfolgenden Verhaltensweisen bei einem anderen Autofahrer. Wie bewerten Sie dieses Verhalten?

	sehr negativ -5	-4	-3	-2	-1	weder noch 0	1	2	3	4	sehr positiv 5
Einem langsameren Fahrzeug so dicht auffahren, dass der vorgeschriebene Sicherheitsabstand zur Hälfte unterschritten wird (z.B. 25 Meter bei 100 km/h)											
Über eine durchgezogene Mittellinie fahren, um zu überholen											
Den vorgeschriebenen Sicherheitsabstand einhalten (Daumenregel "halber Tacho", z.B. 50 Meter bei 100 km/h)											
Den vorgeschriebenen Sicherheitsabstand knapp unterschreiten (z.B. 40 Meter bei 100 km/h)											
Einem anderen Fahrer eine beleidigende Geste zeigen											
Einem langsameren Fahrzeug bis auf wenige Meter auffahren, so dass die Scheinwerfer im Rückspiegeln nicht zu sehen sind ("drängeln")											
Auf der rechten Spur überholen											
Einen anderen Fahrer verbal beleidigen											
Auf einer Straße mit mindestens drei Fahrspuren in einem Zug über zwei Fahrspuren fahren (z.B. von ganz rechts nach ganz links)											

Zurück Weiter



Mercedes-Benz

6%

Stellen Sie sich vor, Sie beobachten die nachfolgenden Verhaltensweisen bei einem anderen Autofahrer. Wie bewerten Sie dieses Verhalten?

	sehr negativ -5	-4	-3	-2	-1	weder noch 0	1	2	3	4	sehr positiv 5
Beim Abbiegen oder Spurwechsel nicht blinken											
Auf der Autobahn bis zu 20 km/h schneller fahren als erlaubt											
Im Toleranzbereich der erlaubten Höchstgeschwindigkeit fahren (z.B. 3 km/h bei Geschwindigkeiten unter 100 km/h)											
Knapp vor einem anderen Fahrzeug in dessen Spur einscheren („reindrängeln")											
Rechtzeitig vor dem Abbiegen oder Spurwechsel blinken											
Auf der Autobahn bis zu 10 km/h schneller fahren als erlaubt											
Auf der Autobahn deutlich mehr als 20 km/h schneller fahren als erlaubt											
Erst kurz vor dem Abbiegen oder Spurwechsel blinken											
Einem langsameren Fahrzeug mittels Lichthupe signalisieren, dass es Platz machen soll											

Zurück Weiter

Mercedes-Benz

8%

Emotionale Fahrzeuganwendungen

Sie haben soeben verschiedene Fahrsituationen bewertet, die in Ihnen Emotionen wie Freude oder Ärger auslösen können. Nachfolgend stellen wir Ihnen verschiedene Anwendungen vor, deren Ziel es ist, positive Emotionen beim Autofahren zu fördern und negative zu minimieren.

Wir bitten Sie an dieser Stelle **nicht über die technische Umsetzung** dieser Anwendungen nachzudenken. Uns interessiert, wie Ihnen die vorgestellten Ideen grundsätzlich **gefallen** und wie **nützlich und innovativ** Sie diese finden.

Zurück Weiter

Mercedes-Benz

10%

Emotionsadaptiver Geschwindigkeitslimiter

Studien haben gezeigt, dass verärgerte Fahrer häufiger zu schnell fahren und Geschwindigkeitsbegrenzungen überschreiten. Das System soll den Fahrer darin unterstützen, sich auch unter dem Einfluss starker Emotionen an bestehende Geschwindigkeitslimits zu halten. Erkennt das System, dass der Fahrer verärgert ist, wird ein Druckpunkt auf dem Gaspedal aktiviert, der es erschwert, das Pedal vollständig durchzudrücken. Dabei passt sich der Druckpunkt an das aktuelle Geschwindigkeitslimit an. Konkret bedeutet dies: Drückt der Fahrer das Gaspedal bis zum Druckpunkt, so wird das Geschwindigkeitslimit nicht überschritten. Drückt der Fahrer das Pedal über den Druckpunkt hinaus – spürbar an dem erhöhten Widerstand –, so wird das Geschwindigkeitslimit überschritten.

Bitte kreuzen Sie an, wie Sie die Idee hinsichtlich der folgenden Aspekte bewerten.

Gefällt mir nicht	○	○	○	○	○	**Gefällt mir**
Nicht innovativ	○	○	○	○	○	**Innovativ**
Nicht nützlich	○	○	○	○	○	**Nützlich**

Gibt es etwas, das Sie an dieser Idee verändern oder verbessern würden?

Zurück Weiter

Mercedes-Benz

12%

Emotionaler Fahrcoach

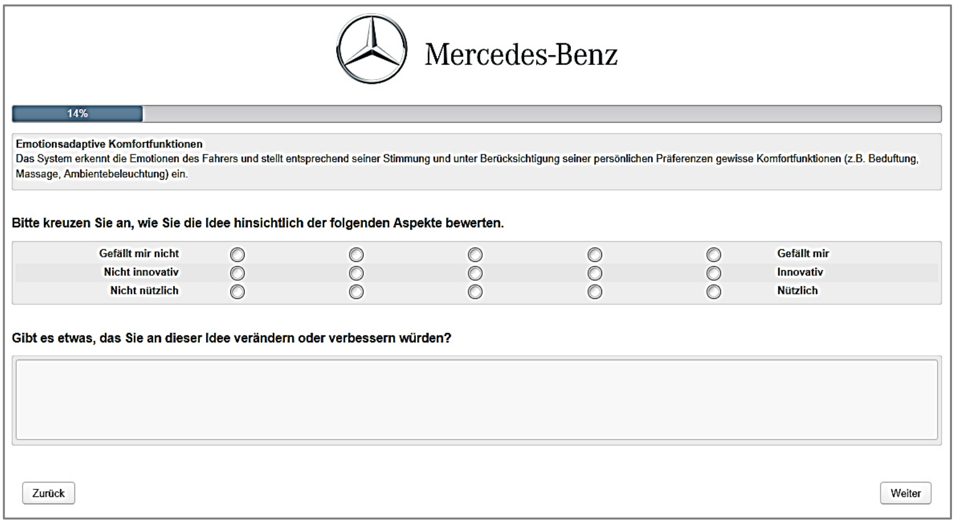
Der Fahrer erhält vom System Feedback bezüglich seines Fahrverhaltens. Dabei erkennt das System "freundliche" Fahrverhaltensweisen (z.B. Sicherheitsabstand einhalten, andere Fahrer einfädeln lassen) und "aggressive" Fahrverhaltensweisen (z.B. Drängeln, Überschreiten des Geschwindigkeitslimits). Für jede freundliche bzw. aggressive Verhaltensweise erhält der Fahrer ein positives bzw. negatives Feedback. Eine Form von negativem Feedback könnte beispielsweise sein, dass sich das Fahrzeug ärgert. Diesen Ärger könnte das Fahrzeug ausdrücken, indem es Assoziationen zur Emotion Ärger schafft, wie eine rote Innenraumbeleuchtung und eine leichte Erhöhung der Innenraumtemperatur.

Bitte kreuzen Sie an, wie Sie die Idee hinsichtlich der folgenden Aspekte bewerten.

Gefällt mir nicht	○	○	○	○	○	**Gefällt mir**
Nicht innovativ	○	○	○	○	○	**Innovativ**
Nicht nützlich	○	○	○	○	○	**Nützlich**

Gibt es etwas, das Sie an dieser Idee verändern oder verbessern würden?

Zurück Weiter



Mercedes-Benz

14%

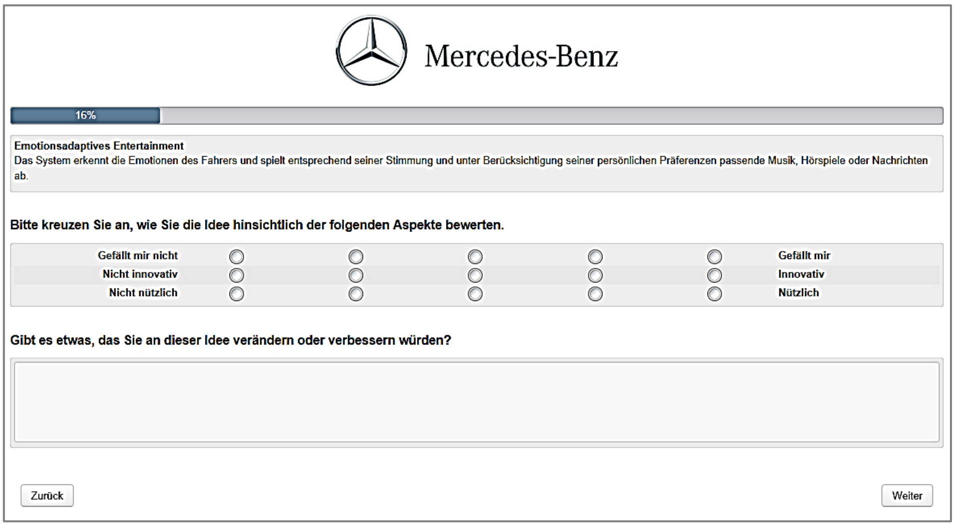
Emotionsadaptive Komfortfunktionen
Das System erkennt die Emotionen des Fahrers und stellt entsprechend seiner Stimmung und unter Berücksichtigung seiner persönlichen Präferenzen gewisse Komfortfunktionen (z.B. Beduftung, Massage, Ambientebeleuchtung) ein.

Bitte kreuzen Sie an, wie Sie die Idee hinsichtlich der folgenden Aspekte bewerten.

Gefällt mir nicht	○	○	○	○	○	Gefällt mir
Nicht innovativ	○	○	○	○	○	Innovativ
Nicht nützlich	○	○	○	○	○	Nützlich

Gibt es etwas, das Sie an dieser Idee verändern oder verbessern würden?

Zurück Weiter



Mercedes-Benz

16%

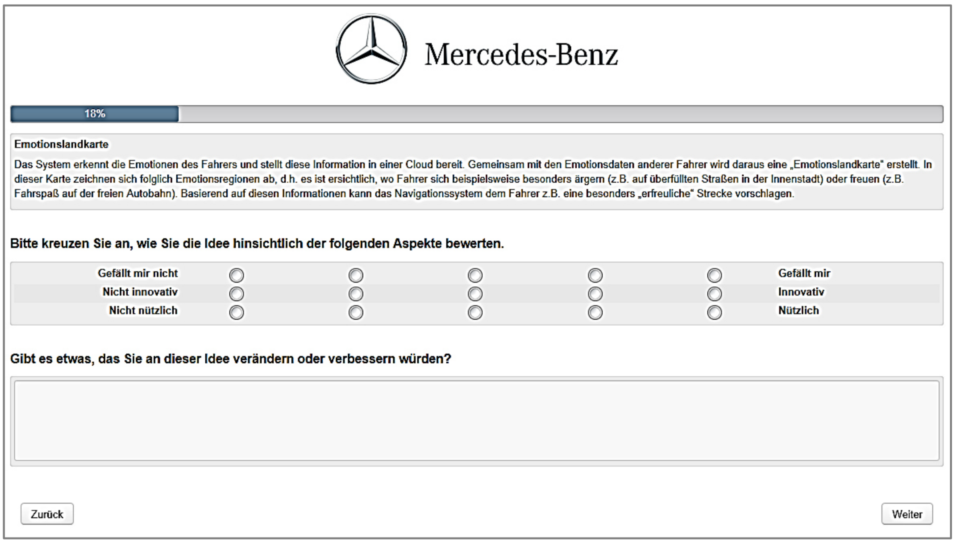
Emotionsadaptives Entertainment
Das System erkennt die Emotionen des Fahrers und spielt entsprechend seiner Stimmung und unter Berücksichtigung seiner persönlichen Präferenzen passende Musik, Hörspiele oder Nachrichten ab.

Bitte kreuzen Sie an, wie Sie die Idee hinsichtlich der folgenden Aspekte bewerten.

Gefällt mir nicht	○	○	○	○	○	Gefällt mir
Nicht innovativ	○	○	○	○	○	Innovativ
Nicht nützlich	○	○	○	○	○	Nützlich

Gibt es etwas, das Sie an dieser Idee verändern oder verbessern würden?

Zurück Weiter


Mercedes-Benz

18%

Emotionslandkarte

Das System erkennt die Emotionen des Fahrers und stellt diese Information in einer Cloud bereit. Gemeinsam mit den Emotionsdaten anderer Fahrer wird daraus eine „Emotionslandkarte“ erstellt. In dieser Karte zeichnen sich folglich Emotionsregionen ab, d.h. es ist ersichtlich, wo Fahrer sich beispielsweise besonders ärgern (z.B. auf überfüllten Straßen in der Innenstadt) oder freuen (z.B. Fahrspaß auf der freien Autobahn). Basierend auf diesen Informationen kann das Navigationssystem dem Fahrer z.B. eine besonders „erfreuliche“ Strecke vorschlagen.

Bitte kreuzen Sie an, wie Sie die Idee hinsichtlich der folgenden Aspekte bewerten.

Gefällt mir nicht	○	○	○	○	○	Gefällt mir
Nicht innovativ	○	○	○	○	○	Innovativ
Nicht nützlich	○	○	○	○	○	Nützlich

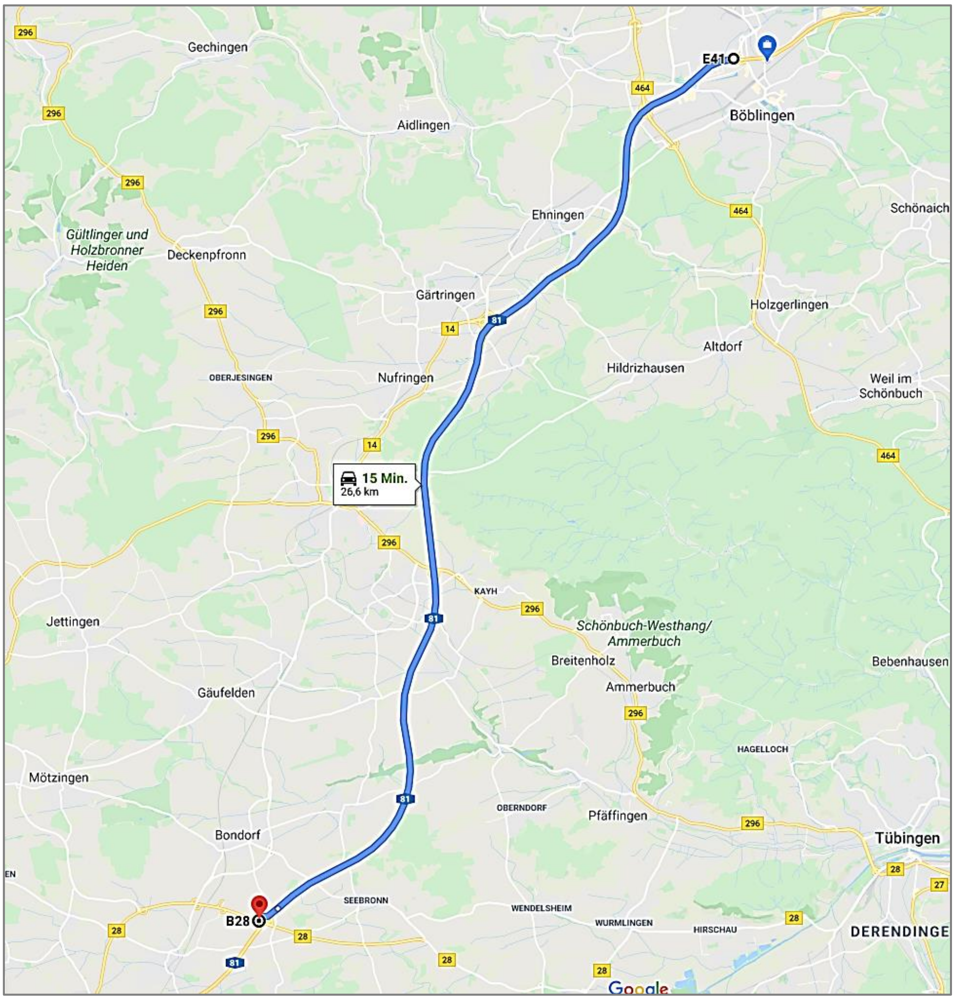
Gibt es etwas, das Sie an dieser Idee verändern oder verbessern würden?

Zurück

Weiter

A.5 Appendix Chapter VII

Appendix 5.1. Test route of the experimental driving study.



Appendix 5.2. Instruction of the experimental driving study.

DAIMLER

Instruktion

- Wir arbeiten an der Entwicklung eines Assistenzsystems, das den **Fahrer beim Fahren auf der Autobahn entlasten** soll. Dazu interessiert uns, welche **Fahrmanöver** – also zum Beispiel Spurwechsel, Überholvorgänge, usw. –bei einer Autobahnfahrt **besonders häufig vorkommen**.

- Daher wollen wir heute **Ihr natürliches Fahrverhalten beobachten**. Beobachten heißt, in diesem Fahrzeug ist ein Computer verbaut, der sämtliche Fahrdaten aufzeichnet und die später ausgewertet werden. Ihre Aufgabe ist es heute einfach so zu fahren, wie Sie das auch tun würden, wenn das hier kein Versuch wäre. Uns interessieren Fragen wie: **Wie dicht fahren Sie für gewöhnlich auf? Wie schnell fahren Sie? Wann blinken Sie? Wie ist ihr Spurwechsel- und Überholverhalten?** Nur wenn sie so fahren wie unter normalen Bedingungen auch, können wir unser System später entsprechend an Ihre Gewohnheiten passen.

- Lediglich die **Assistenzsysteme**, also zum Beispiel Tempomat, Spurhalteassistent, usw., dürfen Sie heute **nicht verwenden**. Es geht uns ja um Ihr *natürliches* Fahrverhalten. Ich werde mich gleich hinter Sie setzen und **begleite** die Fahrt. Ich bitte Sie jedoch, nicht mit mir zu reden. Ich habe nur ein Auge auf die Technik und schaue, ob auch alles so funktioniert, wie es soll. **Tun Sie einfach so, als bin ich nicht da.**

- Noch kurz zu unserer Fahrt: Sie folgen dem Navigationssystem, das ich gleich für Sie einstellen werde. Die Route führt in Richtung Herrenberg über die A8 und wieder zurück und dauert ca. 45 Minuten. Falls es Stau geben sollte, kürzen wir ab. Aber das werde ich Ihnen dann sagen. Ansonsten werde ich, wie bereits erwähnt, nicht mit Ihnen reden.

Falls Fahrt mit System bitte fortfahren: (Hinweis: Wort „Aggression“ nicht nutzen)

- Was Sie hier sehen, ist der Prototyp eines Fahrer-Assistenzsystems, das auf Ihr Verhalten reagiert.

- Das System funktioniert ähnlich wie Fahrer-Assistenz-Systeme für einen ökologischeren Fahrstil. Diese Systeme beobachten z.B. wie sanft Sie beschleunigen und bremsen. Je nachdem erhalten Sie dann einen Eco-Score oder eine Animation z.B. wie diese Blumenranke, die wächst.

- Ähnlich funktioniert auch unser neues System nur, dass es nicht auf Verhaltensweisen achte, die für einen ökologischen Fahrstil sprechen, sondern die als **unangemessen** gelten. Konkret achtet es auf Ihre **Geschwindigkeit, den Abstand zu anderen Fahrzeugen, Blink- und Spurwechselverhalten, Gestik und verbale Ausdrücke.**

- [**Demo zeigen**] Abhängig davon, wie Sie fahren, verändert sich die Animation, die Sie hier sehen: Fahren Sie angemessen, wird die Animation stufenweise blauer, was für einen positiven Zustand des Systems stehen soll. Die Botschaft dahinter ist „**Mein Fahrstil ist gut für mein Fahrzeug und Andere**“. Fahren Sie hingegen unangemessen, wird die Animation stufenweise roter, was einen negativen Zustand repräsentiert, heißt „**Mein Fahrstil ist schlecht für mein Fahrzeug und Andere**“. Haben Sie das Prinzip soweit verstanden?

- Wenn Sie genug von der Demo gesehen haben, starten wir. Das System wird erst aber der Autobahnauffahrt aktiviert, bis dahin sehen Sie nur einen schwarzen Bildschirm. Dann wird das System wird während der gesamten Fahrt aktiv sein.

- **Wichtig**: Ich bitte Sie, die Systemgrenzen nicht künstlich auszureizen, d.h. mit Absicht so zu fahren, dass das System z.B. rot wird. Fahren Sie einfach ganz normal.

Sicherheitseinweisung und Instruktion

DAIMLER

Sicherheitsmaßnahmen

Bitte Punkt-für-Punkt mit dem Teilnehmer durchgehen!

- ☐ **Auszahlung der Aufwandsentschädigung** auch bei Nicht-Antritt, Abbruch oder Unterbrechung der Studie
- ☐ Nicht-Antritt, Abbruch oder Unterbrechung in **Eigenverantwortung des Teilnehmers** bei Stress, Müdigkeit, Unwohlsein, Überforderung etc.
- ☐ **Anweisungen der Versuchsleitung** hinsichtlich Streckenänderung, Abbruch oder Unterbrechung der Studie ist Folge zu leisten
- ☐ Einhalten der **StVo**
- ☐ **Sonnenbrille oder andere Sehhilfen** erlaubt
- ☐ **Fahrzeug einstellen** (Lenkrad, Spiegel, Sitz, etc.)
- ☐ **Nur bei Systemfahrt:** **Prototyp** kann **jederzeit deaktiviert** werden, sofern er ablenkt

Sicherheitseinweisung und Instruktion

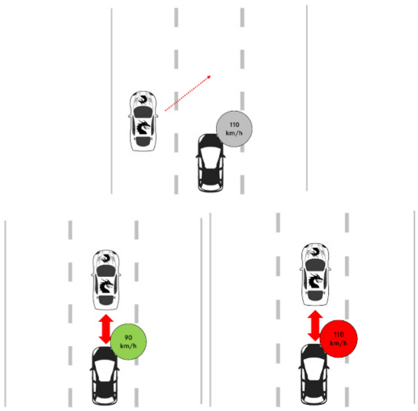
Appendix 5.3. Annotation guideline of the experimental driving study.

Annotationsleitfaden

Dichtes Auffahren

Geschwindigkeit > 80 km/h *und mindestens eines der folgenden Kriterien muss zutreffen:*

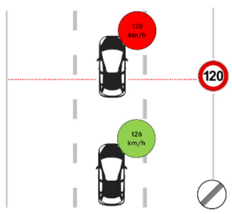
1. Subjektives Gefühl „zu nah"
2. Mindestens „Abstand halber Tacho" unterschritten (bitte an Leitplanken orientieren)
3. FCW-Icon aktiv
4. **Sonderfall**: Geringer Abstand zu Vordermann, weil (1) dieser einen Spurwechsel auf die Ego-Spur durchführt (z.B. sich reindrängelt) ODER (2) dieser bremst ODER (3) das Ego-Fahrzeug einen Spurwechsel auf die Spur eines anderen Fahrzeugs durchführt; der Proband zeigt dabei innerhalb der nächsten Sekunden nach dem Spurwechsel keine Initiative, den notwendigen Sicherheitsabstand (z.B. durch verlangsamen der Geschwindigkeit) wiederherzustellen.



Geschwindigkeitsüberschreitung

Geschwindigkeit > 80 km/h *und das folgende Kriterium muss zutreffen:*

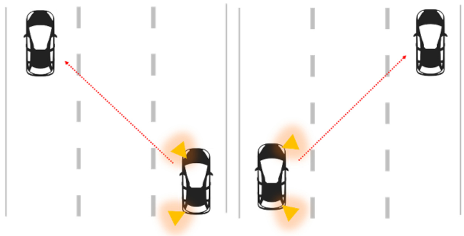
- Gefahrene Geschwindigkeit mind. 10 km/h höher als erlaubte Geschwindigkeit (Geltungsbereich ab Verkehrszeichen)



Spurwechsel über zwei Spuren

Eines der folgenden Kriterien muss zutreffen:

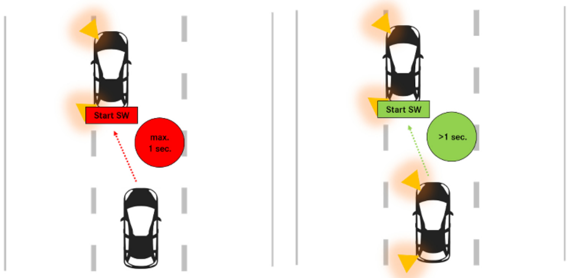
1. In einem Zug über mehrere Spuren fahren (typisch z.B. beim Auffahren auf die Autobahn)
2. Nach einem Spurwechsel verweilt der Fahrer weniger als 2 Sekunden auf der Zielspur führt sofort den nächsten Spurwechsel



Blinken

Eines der folgenden Kriterien muss zutreffen:

1. Spurwechsel/Überholvorgang **ohne** zu blinken
2. Spurwechsel/Überholvorgang beginnt sofort (max. 1 sec.) nachdem geblinkt wurde



Gesten

Eines der folgenden Kriterien muss zutreffen:

1. Bedrohliche Gesten (z.B. Hände bedrohlich heben)
2. Beleidigende Gesten (z.B. Mittelfinger, Vogel zeigen)

Verbale Äußerungen

Eines der folgenden Kriterien muss zutreffen:

1. Beleidigungen (z.B. Arschloch, Depp, Wichser)
2. Negative Kritik an anderen Verkehrsteilnehmern oder der Verkehrssituation (z.B. „Das regt mich echt tierisch auf!“, „Boa, kann der sich mal verpissen?!“, „Wie fährt der denn bitte?!“)

Appendix 5.4. Interview guideline of the experimental driving study.

Systemfragebogen **Pn.Nr.** ______________

Ganz allgemein: Haben Sie auf das System **geachtet**?

☐ **System nicht beachtet**

Was glauben Sie, auf welche **Fahrverhaltensweisen** hat das System **reagiert**?

Hat Sie das System **irritiert**, was hat sie **gestört**?

Sonstige **Anmerkungen**:

Appendix 5.5. Questionnaire of the experimental driving study.

Auf den nachfolgenden Seiten interessiert uns zunächst Ihr Gesamteindruck von der heutigen Fahrt und dem Fahrzeug, das Sie dabei gefahren sind.

WEITER

Wie haben Sie den Umgang mit dem Fahrzeug - über die gesamte Fahrt hinweg betrachtet - erlebt?

sehr ungewohnt	○	○	○	○	○	○	○	sehr natürlich

Wie stark unterscheidet sich die Art und Weise, wie Sie heute im Versuch gefahren sind, zu Ihrem "normalen" Fahrstil?

				Ich bin gefahren wie immer				
Ich habe weniger Abstand zu anderen Fahrzeugen gehalten	○	○	○	○	○	○	○	Ich habe mehr Abstand zu anderen Fahrzeugen gehalten
Ich habe häufiger geflucht als sonst	○	○	○	○	○	○	○	Ich habe seltener geflucht
Ich bin schneller gefahren	○	○	○	○	○	○	○	Ich bin langsamer gefahren
Ich habe später geblinkt	○	○	○	○	○	○	○	Ich habe früher geblinkt
Ich habe seltener geblinkt	○	○	○	○	○	○	○	Ich habe häufiger geblinkt

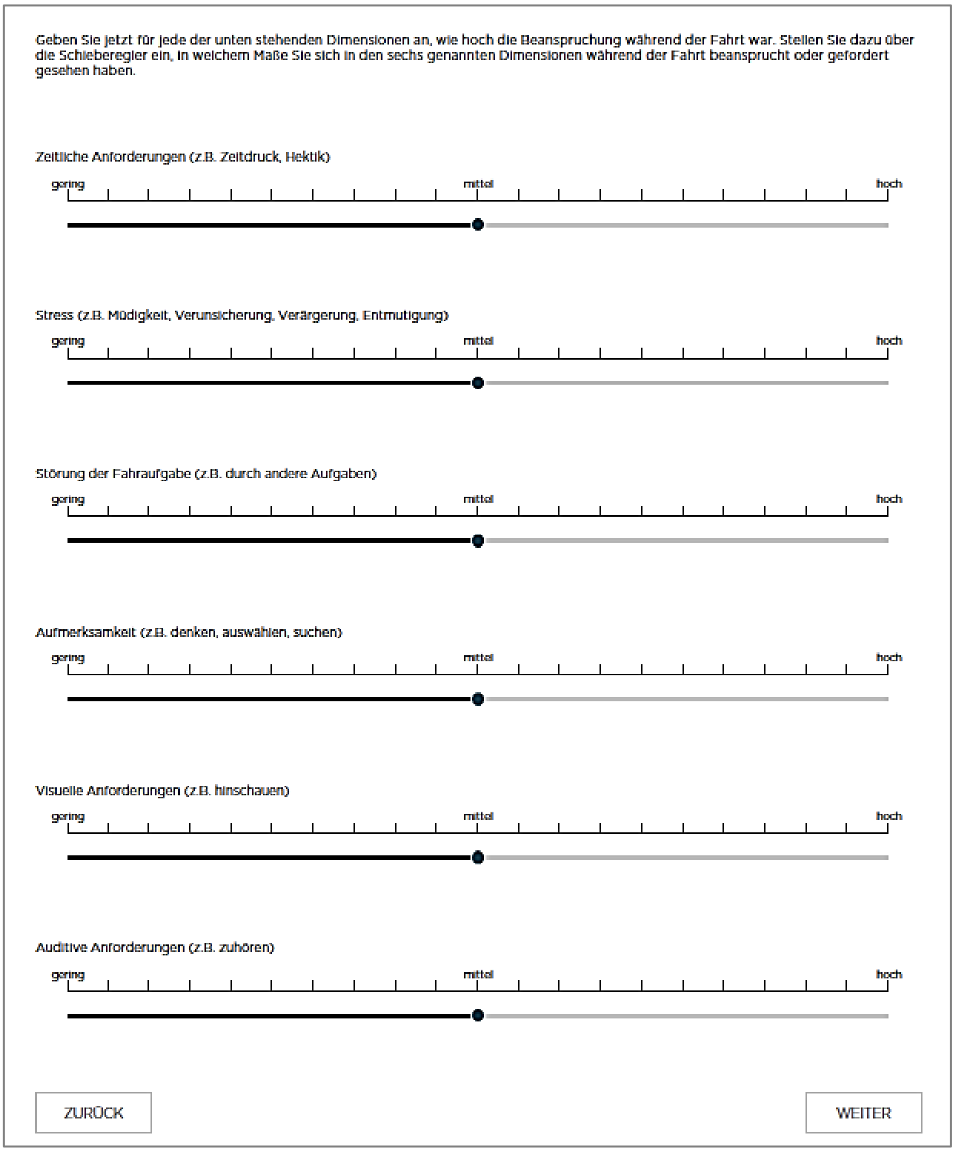
ZURÜCK WEITER

Nun geht es um eine Einschätzungen Ihres eigenen Verhaltens im Straßenverkehr.
Wie aggressiv schätzen Sie Ihr eigenes Fahrverhalten ein?

Gar nicht aggressiv	Wenig aggressiv	Durchschnittlich	Aggressiv	Sehr aggressiv
○	○	○	○	○

Wie äußert sich das?

ZURÜCK WEITER


Geben Sie jetzt für jede der unten stehenden Dimensionen an, wie hoch die Beanspruchung während der Fahrt war. Stellen Sie dazu über die Schieberegler ein, in welchem Maße Sie sich in den sechs genannten Dimensionen während der Fahrt beansprucht oder gefordert gesehen haben.

Zeitliche Anforderungen (z.B. Zeitdruck, Hektik)

gering mittel hoch

Stress (z.B. Müdigkeit, Verunsicherung, Verärgerung, Entmutigung)

gering mittel hoch

Störung der Fahraufgabe (z.B. durch andere Aufgaben)

gering mittel hoch

Aufmerksamkeit (z.B. denken, auswählen, suchen)

gering mittel hoch

Visuelle Anforderungen (z.B. hinschauen)

gering mittel hoch

Auditive Anforderungen (z.B. zuhören)

gering mittel hoch

ZURÜCK WEITER

Bitte geben Sie anhand der folgenden Aussagen an, wie Sie sich während der Fahrt gefühlt haben.

	überhaupt nicht	ein wenig	mittelmäßig	ziemlich	außerordentlich
Ich fühlte mich herausgefordert.	○	○	○	○	○
Ich fand es beeindruckend.	○	○	○	○	○
Ich musste mich sehr anstrengen.	○	○	○	○	○
Ich war zufrieden.	○	○	○	○	○
Ich fand es ermüdend.	○	○	○	○	○
Ich habe mich gut gefühlt.	○	○	○	○	○
Ich habe mich gelangweilt.	○	○	○	○	○
Ich habe mich kompetent gefühlt.	○	○	○	○	○
Ich habe sehr darauf geachtet, wie ich fahre	○	○	○	○	○
Ich fühlte mich frustriert.	○	○	○	○	○
Ich habe mich erfolgreich gefühlt.	○	○	○	○	○
Ich habe alles um mich herum vergessen.	○	○	○	○	○
Ich war gereizt.	○	○	○	○	○
Ich war komplett vertieft.	○	○	○	○	○

ZURÜCK WEITER

Sie haben auf der heutigen Fahrt ein System kennen gelernt, das Ihnen Feedback zu Ihrem Fahrverhalten gibt.

Auf den nachfolgenden Seiten möchten wir Ihnen speziell zu diesem Feedback-System ein paar Fragen stellen.

(Hinweis: Sie müssen das Video nicht bis zum Ende anschauen und können jederzeit auf "weiter" drücken")

ZURÜCK WEITER

Bitte geben Sie mit Hilfe der folgenden Wortpaare Ihren Eindruck zum Feedback-System wieder.

ineffizient	○	○	○	○	○	○	○	effizient
abstoßend	○	○	○	○	○	○	○	anziehend
wertvoll	○	○	○	○	○	○	○	minderwertig
gut	○	○	○	○	○	○	○	schlecht
behindernd	○	○	○	○	○	○	○	unterstützend
unerfreulich	○	○	○	○	○	○	○	erfreulich
kreativ	○	○	○	○	○	○	○	phantasielos
unverständlich	○	○	○	○	○	○	○	verständlich
unangenehm	○	○	○	○	○	○	○	angenehm
aktivierend	○	○	○	○	○	○	○	einschläfernd
kompliziert	○	○	○	○	○	○	○	einfach

ZURÜCK WEITER

Bitte geben Sie anhand der folgenden Aussagen an, was Sie gegenüber dem Avatar empfinden.

Antworten Sie einfach aus Ihrem Bauchgefühl heraus, wenn Ihnen einige Aussagen zunächst ein wenig unpassend erscheinen.

	überhaupt nicht	ein wenig	mittelmäßig	ziemlich	außerordentlich
Der Avatar macht mich froh	○	○	○	○	○
Ich habe keine Gefühle gegenüber dem Avatar	○	○	○	○	○
Der avatar enttäuscht mich	○	○	○	○	○
Ich habe beschützende Gefühle gegenüber dem Avatar	○	○	○	○	○
Der Avatar macht mich aggressiv	○	○	○	○	○
Ich bin dem Avatar gegenüber nachtragend	○	○	○	○	○
Ich habe liebevolle Gefühle gegenüber dem Avatar	○	○	○	○	○
Ich mag den Avatar nicht	○	○	○	○	○

ZURÜCK WEITER

Haben Sie sich vom Feedback-System bevormundet gefühlt?

gar nicht						sehr
○	○	○	○	○	○	○

ZURÜCK WEITER

Appendix 5.6. Descriptive statistics of the user experience items.

Item	*Min*	*Max*	*M*	*SD*
Attractiveness				
enjoyable - annoying	1.00	6.00	2.84	1.37
good - bad	1.00	5.00	2.74	1.26
pleasing - unlikable	1.00	6.00	3.23	1.31
pleasant - unpleasant	1.00	6.00	2.55	1.26
Overall attractiveness	1.00	5.50	2.84	1.16
Pragmatic quality				
understandable - not understandable	1.00	5.00	2.29	1.10
easy - complicated	1.00	4.00	1.84	.90
supportive - obstructive	1.00	7.00	2.84	1.32
efficient - inefficient	1.00	6.00	3.23	1.36
Overall pragmatic quality	1.00	4.75	2.55	.92
Hedonic Quality				
creative - dull	1.00	7.00	2.81	1.38
valuable - inferior	1.00	7.00	3.10	1.47
motivating - demotivating	1.00	6.00	3.23	1.48
Overall hedonic quality	1.33	6.67	3.04	1.14
User experience score	1.19	4.75	2.81	.94

N = 31; scale: 1 positive pole – 7 negative pole

Appendix 5.7. Descriptive statistics of the gaming experience items.

	System				Baseline			
Item	*Min*	*Max*	*M*	*SD*	*Min*	*Max*	*M*	*SD*
I felt successful	1	5	2.88	1.21	1	5	2.63	1.36
I felt bored*	1	4	1.69	.97	1	3	1.63	.75
I found it impressive	1	5	2.56	1.13	1	5	2.13	1.21
I forgot everything around me	1	4	1.81	.97	1	4	1.88	.98
I felt frustrated*	1	1	1.00	.00	1	3	1.06	.35
I found it tiresome*	1	4	1.66	1.00	1	4	1.41	.80
I felt irritable*	1	4	1.22	.66	1	3	1.09	.39
I felt skillful	1	5	3.50	1.14	1	5	3.34	1.15
I felt completely absorbed	1	5	2.19	1.12	1	4	2.19	1.00
I felt content	1	5	4.06	.88	1	5	3.88	1.01
I felt challenged	1	5	1.50	.84	1	4	1.38	.71
I had to put a lot of effort into it*	1	2	1.22	.42	1	3	1.19	.47
I felt good	3	5	4.25	.51	1	5	4.13	.75
Gaming experience score	2.69	4.69	3.54	.42	2.54	4.62	3.47	.41

N = 32; scale: 1 “not at all”, 2 “slightly”, 3 “moderately”, 4 “fairly”, 5 “extremely”
* inverse formulated and transcoded for the calculation of the gaming experience score

Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG