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Towards the Healing Car: Investigating the Potential of Psychotherapeutic In-vehicle Interventions

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TOWARDS THE HEALING CAR: INVESTIGATING THE POTENTIAL OF PSYCHOTHERAPEUTIC IN-VEHICLE INTERVENTIONS

Research in Progress

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Abstract

The globally increasing prevalence and incident rates of mental diseases is one of the most serious public health challenges according to the World Health Organization. Today, treatment is based on professional therapies which require a high amount of financial resources and personnel effort, however IT-supported interventions in ubiquitous devices promise help and a new leverage beyond traditional therapies. We identify the car as a space for new treatments since drivers often have time and the environment in the automobile is highly controlled. In-vehicle information systems can reach people in their daily routine and could introduce innovative prevention measures. In this research in progress paper, we address the open question how the car can improve a driver's affective state while driving. First, we thoroughly describe the design of a study we conducted to motivate other researchers for this topic. Second, we analyse 631 completed interventions collected in a 2-month field study with 10 drivers. First analyses indicate that we can positively influence the short-term affective state of drivers with at least one of our intervention types. We provide first practical examples of how to reach the masses of everyday drivers.

Keywords: Mindfulness, Music, Intervention, In-Vehicle Information Systems, Field Experiment, Affective State.

1 Introduction

In 2017 the World Health Organization reported that about 320 million people worldwide suffer from depression and 264 million from anxiety disorders (World Health Organization, 2017), a ten year increase of 18.4% for depression and 14.9% for anxiety disorders (Vos et al., 2016). New estimates account mental illnesses for around one third of all years of potential life lost due to premature mortality and around 13% years of productive life lost due to disability (Vos et al., 2016). Information systems (IS) are already improving the state and behaviour of people in a sustainable way (Tiefenbeck et al., 2016; Weinmann et al., 2016; Kowatsch et al., 2017) including the field of psychotherapy, where IS allows new opportunities such as online or app-based therapies (Schröder et al., 2018; Boschloo et al., 2019). Nevertheless, detection and treatment remain a challenge and still require intensive personal care from doctors and psychotherapists (Greenberg et al., 2015; Kuyken et al., 2015). Hence, as of today, the field of prevention and treatment of mental disorders still lacks scalable and low-cost treatment measures whereas IS could act even more as an enabler to reach people in their daily life (Agarwal et al., 2010; Kvedar et al., 2016; Berger et al., 2019).

Latest research has recognized the potential of highly scalable and low cost in-vehicle interventions to address the aforementioned challenges, particularly in the realm of commuting (Paredes et al., 2018; Balters et al., 2019; Zepf et al., 2019). Everyday commuting by car is a life reality for many people. In Germany, for example, over 60% of the working population uses a car to commute (Statistisches Bundesamt, 2017). In addition, people spend a significant time commuting. Alone in 2008 over 25% of the German car commuters spent more than 1 hour daily in their cars. Furthermore, commuters are in a private environment, most often without additional passengers (infas and DLR, 2008). Building upon these opportunities, our research is geared towards the vision of the healing car. We want to investigate if highly scalable in-vehicle interventions can improve well-being and health of commuters. In the long term, we specifically aim at mental illnesses such as depression. However, in an early and exploratory phase, we want to investigate if the affective state of healthy drivers that show no signs of a mental illness can be improved in order to gain an initial understanding of feasibility and effect sizes of in-vehicle interventions. To the best of our knowledge, there is no empirical evidence on affective in-vehicle interventions that were conducted in real traffic over a substantial amount of time. Hence, we aim to address the following research question:

> *RQ: To what extend can the affective state of car drivers be improved by in-vehicle interventions based on well-established psychotherapeutic treatment concepts?*

In order to approach this research question, we developed two audio-based in-vehicle interventions in close collaboration with psychotherapists and driving safety experts. We evaluated these interventions during a field study in the wild with 10 participants. Over a period of 4 months, the participants received a car equipped with various data collection sensors to carry out their daily trips. In the first 2 months, we only collected data on driving behaviour to later infer a driver's affective state, a research aim that we do not further investigate in this paper. For the remaining 2 months we delivered our interventions in the car and the participants rated their affective state before and after each trip as well as after each completed intervention. In this paper, we present our study approach, the interventions, and preliminary results. Thereby, we particularly focus on the intervention design. Ultimately, we provide the first practical evidence that the affective state of drivers can be improved based on in-vehicle interventions adopted from established psychotherapeutic concepts.

2 Theoretical Background and Related Work

2.1 Affective State, Mental Disorders, and Psychotherapeutic Treatment

The term affective state describes the experience of feeling an underlying emotional state (Schwarz, 1990). These states can arise from different feelings: short and raw (affect), directed and intense sensed

periods (emotions), or long lasting and diffuse (moods) (Schwarz, 1990; Barrett, 2006). In affective computing, these terms are often used interchangeably (Calvo and Mello, 2010) and even in psychology, there exists yet no consensus concerning a general classification (Frijda, 1988; Ekman and Davidson, 1994; Izard, 2009). Instead, research distinguishes between two approaches that usually assess emotions as a measure of affective states (Calvo and Mello, 2010). Categorical models represent emotions by discrete categories. A popular example is the "wheel of emotions" which differentiates between 8 basic emotions such as joy, anger, or love with different intensity levels (Plutchik, 2001). In contrast, dimensional models allow the mapping of emotions into a multidimensional space. A commonly used two-dimensional model is Russel's circumplex model of arousal and valence (Russell, 1980). The arousal axis indicates the activation level, e.g. how tired or energised someone is. On the valence axis, the rating measures the happiness level. In addition to the simplicity, its attractiveness may have two reasons. First, different levels of arousal and valence allow to infer various emotions, e.g. a high level of both suggests excitement, a high arousal and low-level valence implies being upset. Second, the measurement of both dimensions is ecological and cross-cultural possible as measures as the Self-Assessment Manikins exist (Bradley and Lang, 1994; Morris, 1995). The two dimensions arousal and valence can serve as a reliable proxy measurement in clinical and non-clinical contexts such as emotions (Bradley and Lang, 1994), stress (Oldehinkel et al., 2011; Kowatsch et al., 2017), or even depressions (Ringeval et al., 2019).

Depression, especially Major Depression Disorder as an exemplary mental disorder, has a negative effect on the way a person thinks, feels, and acts, which many mental disorders share (American Psychiatric Association, 2013). Explicitly, depressed patients often exhibit either extremes or no variance in their affective state depending on their depression symptoms which can consist of signs of dysphoric mood, social withdrawal and self-neglect, hypersomnia or insomnia, poor appetite or overeating, loss of energy or fatigue, low self-esteem, and poor concentration or difficulty making decisions (World Health Organisation, 1992; American Psychiatric Association, 2013). Accordingly, a different term for *mental disorders* is *affective disorders* (World Health Organisation, 1992).

The described extremes or missing variances in one's affective state is an indication of a mental disorder. Psychotherapists today use Cognitive Behavioural Therapies (CBT) to raise people's awareness of their emotions and support their regulation by challenging patterns and beliefs and replacing errors in thinking (Beck and Beck, 1995). CBT are regarded as the gold standard in psychotherapy and are also the guideline for many psychotherapeutic methods (David et al., 2018; Hayes and Hofmann, 2018). CBT-based treatments span over several weeks with weekly therapy sessions in which patients are treated with a mixture of various practices as psychoeducation, meditations, methods for positive emotion inducement, or behavior change exercises amongst others (Kabat-Zinn, 1982; Teasdale et al., 2000). They all show effects in mentally ill people, but some of them also in healthy people, e.g. mindfulness meditation reduces stress (Gu et al., 2015; Khoury et al., 2015) or music improves the mood (Lynar et al., 2017).

2.2 In-vehicle Interventions for Well-being and Health

In recent years, research and real-world applications on influencing the driver state have gained on importance as today's cars offer more and more technological capabilities. Nowadays, manufactures ship cars with an increasing amount of computing power as well as comfort and autonomous features. A convenient approach is to adapt the existing comfort features and systems in the car, for example by adapting the ambient lightning to react to the driver state, modifying proposed navigation routes to choose calmer routes, or automating air-climate control to increase well-being (Hernandez et al., 2014). However, new types of interventions are as well discussed. In a study in which passengers were shown mindful and relaxing virtual reality content during the journey, the authors showed that these experiences can reduce arousal and prevent motion sickness, but the experience must be carefully designed (Paredes et al., 2018). Further, Paredes et al. (2017) inspect how to transfer a proven psychotherapeutic breathing intervention into the car. They developed and empirically validated a breathing exercise in a driving simulator to positively influence the driver state (Paredes et al., 2017; Paredes et al., 2018). Another open question is when to show interventions. Studies indicate that beyond traffic laws context-aware and adaptive intervention systems must consider additional safety aspects. In a recent research,

the authors measured the stress level while driving to identify when it is safe to deliver interventions. Stress peaks occur e.g. in case of making wrong turns, in certain environments as highways, or when road obstructions appear (Balters et al., 2019). Beyond the safety aspect, various events trigger different emotions in the car and may influence intervention effects as a recent study indicates. Zepf et al. (2019) show several examples, a major finding is that positive emotions arise with goal congruent events such as green lights and low traffic density whereas goal incongruent events are associated with negative emotions. Looking at the automobile manufacturers, we see that they have already announced or even introduced related real-world applications. At the Consumer Electronics Show (CES) 2016, Audi presented the "Audi Fit Driver" program which should adapt the vehicle to the driver's needs by interventions based on wearable sensor data (Audi AG, 2016). Mercedes went ahead with the market launch of a very similar solution called "ENERGIZING" in 2018. By combining the data from a consumer smartwatch and vehicle data, new Mercedes vehicles can suggest possible interventions such as recommending personal music, changes to the air conditioning or ambient light, or the use of seat massage functions (Daimler AG, 2018). The major limitations of these findings are the yet missing application in the field or their validation. The research-based intervention studies only described potential interventions or validated them just in laboratory or artificial settings. The real-world examples have no publications on effects available. Our study aims to shed light on these open issues.

3 Empirical Study Design

We divided our 4-month field experiment into a 2-month phase to collect data of the driver affective states and a 2-month intervention phase. Throughout the study, the participants were not provided with specific driving instructions and continued their daily driving routines. The entire study was examined and approved by the ethics committee of the University of Bern (ethic approval nr. 2019.04-00003) and the cars were inspected and approved by a certified motor vehicle garage to ensure the safety of the participants. In order to test our hypotheses, we mounted a fixed smartphone including a self-developed app in the cars. The app had two purposes: a) collect the affective state of participants before and after driving (questionnaire-based, over the full 4 months) and b) conduct interventions while driving with immediate voice feedback after each intervention (during the 2 months of the intervention phase). We will explain our study design in more detail in this section.

3.1 Data Collection, Measurement Instruments, and Intervention Procedure

In total, 54 people responded to a call for participation by completing a questionnaire on their driving habits. Based on this data, we then determined 10 individuals to join our study. First and foremost, the participants had to have no known mental illnesses and further enough driving time per day to ensure proper data collection. The selected participants were contacted and received their prepared car in a handover session. In total, 4 women and 6 men participated in the study, all ranging within the age of 26 to 55 with an average age of 37.2. During the time of study, all of them were employed by a large German company with several offices in urban and rural areas. The participants reported conducting various activities while driving, e.g. listening to radio and music or calling people.

The custom-made app employed two mechanisms to collect the participants' affective states. The participants rated their affective state before and after the drive by completing a questionnaire that had a processing time of about 1 minute (see Figure 1 A). A major element of this questionnaire was the Affective Slider (Betella and Verschure, 2016), an empirical validated tool to measure arousal and valence similar to the Self-Assessment Manikin (Bradley and Lang, 1994), however adapted for modern user interfaces and devices such as smartphones. With the Affective Slider, the participants could rate on a continuous scale whether they are in phases of low or high levels of arousal and valence.

After the initial questionnaire, the app randomly selected one of the three intervention types (see Section 3.2). For the mindfulness or music intervention, a large play button appeared in the app (see Figure 1 B). With this button, the driver could manually decide when to start the intervention. This design

decision was due to safety considerations. Interventions should only begin when the driver's concentration and environment would allow it. In order to assess the impact of the intervention, we asked for a voice-based feedback right after the intervention (see Figure 1 C). Based on the Affective Slider (Betella and Verschure, 2016) we asked the participants two questions: After the intervention, do you feel a) more aroused and b) happier than before? The participants could reply on a scale from 1 (no change at all) to 5 (very significant change). These questions followed the concept of the Client Oriented Scale of Improvement (COSI) questionnaire (Dillon et al., 1997).

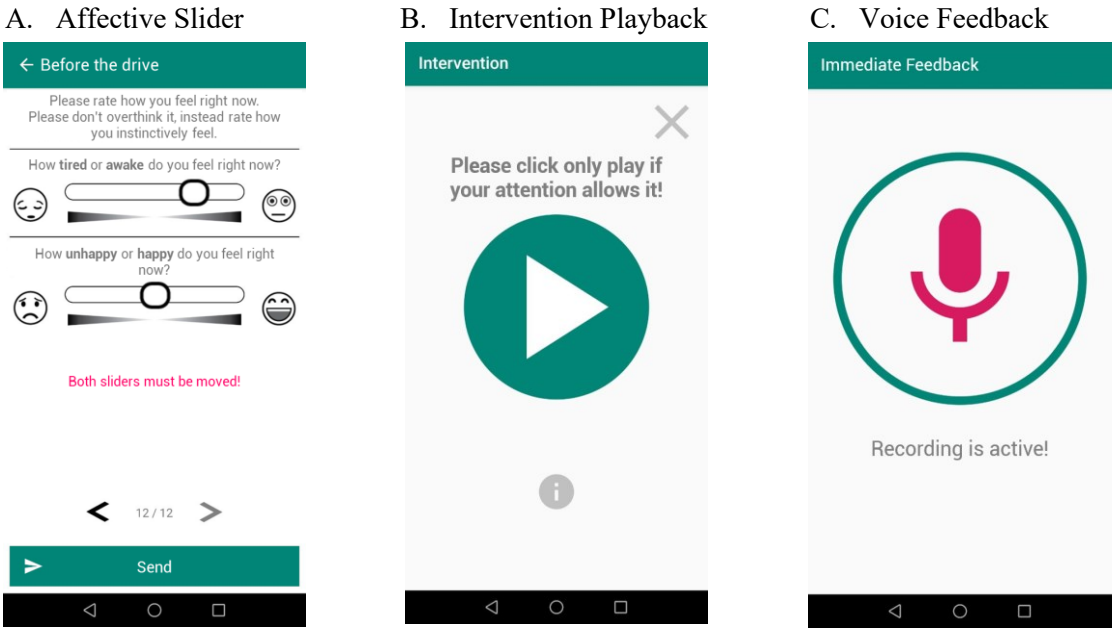

Figure 1. In-vehicle app consisting of Affective Slider questionnaire, playable audio interventions, and immediate voice feedback recording (screens translated)

3.2 Interventions

We have chosen and designed two interventions and a baseline with an interdisciplinary team of engineers, experts of the automotive industry, psychotherapists, and information systems researchers. All interventions originated from exercises in CBT-based programs. As first in-vehicle intervention type, we decided to introduce a mindfulness exercise that is currently popular both in psychotherapy and outside of it (Van Dam et al., 2018), as it benefits both healthy and mentally ill people (Gu et al., 2015). Mindfulness focuses on two aspects, conscious attention on the present and non-judgmental perception (Kabat-Zinn, 1982). The duration of these meditation exercises usually varies between 5 and 20 minutes. They are performed by a slow speaking voice and are interrupted by moments of silence, lasting from a few seconds to several minutes, to explore and understand one's own emotions and their effects (Kabat-Zinn, 1982). Unfortunately, during these meditations participants must often close their eyes and actively concentrate on their body, their emotions, and themselves (Baer, 2003). For obvious reasons, it is not possible to use such active mindfulness in the car (Kabat-Zinn, 1994). However, there are concepts of passive mindfulness that guide participants to focus on the present and current daily tasks so that they perform them more mindful, e.g. showering or climbing stairs (Hede, 2010). We have transferred passive mindfulness elements with a team of experienced psychologists and psychotherapists for the application in the car. In our mindfulness intervention, the participants were educated once about the concept of mindfulness. In subsequent interventions, the passive mindfulness exercise was played. Our exercise had two elements that alternated in blocks to help the participants become aware of the present. The environment-centric elements supported the participants to concentrate on their surroundings and the current driving task. The self-centric elements were designed to aid them focusing on themselves and

their emotions. Table 1 shows an example of each element. Each block included 3 to 6 such elements. The mindfulness intervention started with an environment-centric block, followed by a self-centric section. Both were repeated once before the closing block again emphasized the street and other traffic participants with an environment-centric element. Slow rhythm of speech and breaks of 20 seconds between the elements provided the time necessary for concentration. The mindfulness exercise lasted around 14 minutes. We only introduced one mindfulness intervention, as guidelines suggest to repeat practicing several times to understand and feel the effects of an exercise (Kabat-Zinn, 1982; Teasdale et al., 2000).

Element type	**Text**
Environment-centric	"Start by focusing your attention on yourself in the vehicle. Begin to notice where you come into contact with the interior of the vehicle. You may notice how sitting feels, the feeling of your feet on the floor or pedal, or the pressure of your hands on the steering wheel. Take a moment to connect with the room." [...]
Self-centric	"Now expand your attention to perceive any body feelings you experience. Take a moment to pause and simply allow yourself to observe all the sensations that are present in your body without judging them good or bad and without trying to change them in any way. Just perceive with openness and curiosity what is there." [...]

Table 1. Example elements with text passages for the mindfulness exercise

The second intervention should be based on an activity common to all drivers, but also be established in psychotherapy. Over 90% of people listen to music while driving (Sloboda et al., 2001), therefore we consider music as a reasonable choice. The role of music as affect regulator for healthy and mentally ill people further supports our decision (Erkkilä et al., 2011; Van Goethem and Sloboda, 2011; Koelsch, 2014). Musical features were in the past already inspected for their effects on affective states. Researchers identified that structural elements such as tempo, loudness, or rhythm can generally efficiently change arousal levels, while valence is a very subjective dimension and depends on the listener's preferences (Schubert, 2004; Lynar et al., 2017). This individual dimension of music can be strengthened by recalling autobiographical positive memories with as well positive effects on the arousal level (Jäncke, 2008). The specific usage of these positive memories is a best practice among psychotherapists with yet missing empirical evidence in the wild (Leubner and Hinterberger, 2017; Bernhardt, 2019). We requested a personalized playlist with minimum 10 songs and received playlists with an average of 15.6 songs from each participant. We also asked them to write down a strong positive memory for each song so that they could recall it during the interventions. This remembering follows the best practices and should ensure that the selected songs will positively affect the participants' valence dimension and make them happier. An extract of one person's playlist is shown in Table 2. We defined the minimum playing time for this intervention as 9 minutes, which on average led to 3 played songs per music intervention.

Song	**Artist**	**Connected memories**
Anywhere	Passenger	Our marriage vow (song quote: "I will go anywhere with you")
You Can't Look Back	Taking Back Sunday	Song helped me through a difficult time (strokes of my dad)
Full Steam Spacemachine	Royal Republic	Pushes me a lot when I am stressed

Table 2. Example playlist extract by one participant

As an additional and third intervention type, we introduced the "care-as-usual" principle as the baseline in which no intervention should be played. Instead, participants could perform their normal behavior such as listening to the radio or talk on the phone.

On each trip, one of these interventions was randomly selected, which led to a randomized controlled trial (RCT) intervention setup with a reversal design (Dallery et al., 2014). For increasing the overall quality of the interventions and ensuring acceptance of the drivers, we hired a radio announcer to record

the voice parts. Further, as participants drove in real-world traffic conditions, we also had to pay special attention to safety. Therefore, all interventions were purely audio-based, the drivers could decide when to start with the intervention and pause or even cancel an ongoing one. Furthermore, each intervention was preceded by a short announcement reminding the drivers to be aware of their safety. The participants connected the study smartphone via Bluetooth to the car infotainment system to ensure high audio quality. To comply with safety regulations for using a smartphone in the car, the intervention playback was fully controllable via the steering wheel and the infotainment controls. In addition, we piloted the interventions with 2 drivers unrelated to the study and adapted the interventions according to their feedback.

4 Preliminary Data Analysis and Results

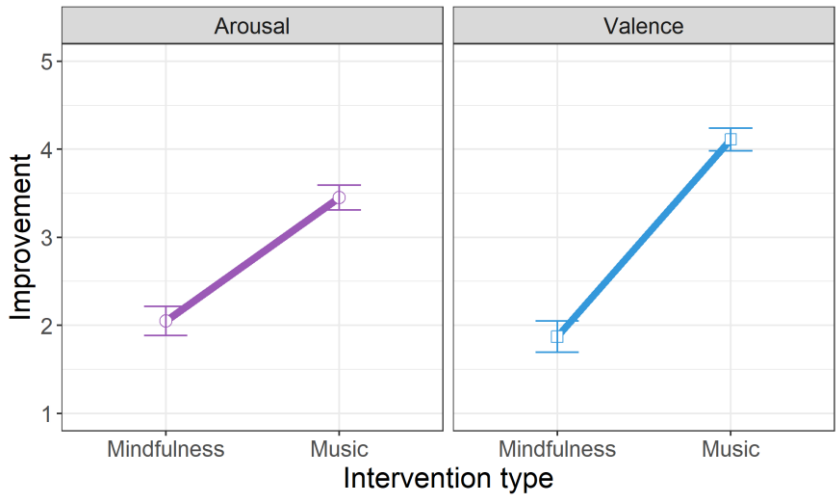

Figure 2. *Voice feedback by intervention type and feedback dimension based on the COSI questionnaire (Dillon et al., 1997) whereas the error bars show the 95% confidence interval, 1: I feel not at all more aroused/happy after the intervention, 5: I feel extremely more aroused/happy after the intervention, 138 completed mindfulness and 175 completed music interventions with n=10*

We analysed our data with R 3.6.1 and by means of a repeated measures analysis of variance (repeated measures ANOVA). In total, the participants successfully played and rated 631 interventions from 1.054 intervention possibilities during the 2 months of our study. The completed interventions split between 175 music, 138 mindfulness, and 318 care-as-usual interventions. The participant with the most interventions completed 102 of them, the one with the fewest 41. In our preliminary comparison, we inspect the voice feedback immediately after a participant completed an intervention as Figure 2 shows. Voice feedback exists for the mindfulness and music interventions. We tested our data on normality and sphericity, no repeated-measures ANOVA conditions were violated. On a scale from 1 (no change at all) to 5 (very significant change), the participants rated an improvement due to the mindfulness intervention with a mean of 2.04 (95% CI +/-0.18) for arousal and with a mean of 1.87 (95% CI +/-0.19) for valence. The ratings of the music intervention are on average 3.45 (95% CI +/-0.15) for arousal and 4.10 (95% CI +/-0.14) for valence. The type of intervention had a significant effect on arousal ($r=0.81$, $p<0.01$) and valence ($r=0.90$, $p<0.001$) both with strong effect sizes measured by Pearson's correlation coefficient.

5 Discussion

5.1 Discussion of Results

Our initial analyses indicate differences by the intervention type. In the short-term voice-based feedback, the participants perceived the music intervention in both affective state dimensions superior to the mindfulness exercise. In our opinion, the personalized emotional experience and self-selection explain the

positive outcome of the music intervention compared to the more rational exercise in form of the mindfulness intervention. The subtle positive effects that emotional memories and music have on emotion-specific functional connections of the brain may not emerge by conducting a rational exercise (Koelsch, 2014). By activating the positive memories, the music intervention inferred a comparable strong impact on valence and arousal as literature indicates (Jäncke, 2008; Lynar et al., 2017). In addition, we argue for two additional possible explanations why the participants perceived the more rational mindfulness intervention exercise less valuable. First, it could be that the overall quality or design of the mindfulness intervention limited the results. Second, the mindfulness intervention distracts people from driving, or driving distracts the concentration that a mindfulness exercise requires. It might be the case that the cognitive load is just too high which limits the effects of an intervention or may even causes negative affective states by frustrations resulting of cognitive overload (Paas et al., 2004; Engström et al., 2017). We tried to eliminate both by performing several pilot and feedback iterations as well as recording the mindfulness intervention with a professional radio announcer, however a more thorough inspection is needed. In addition, we see that some participants rated either the music intervention consistently low or the mindfulness intervention higher. We suspect that no intervention meets all needs and personal tastes. Again, there is the need to explore and understand the interventions in more detail.

5.2 Outlook on Further Analysis

As we are at the beginning of our data analysis, we have several steps in mind how we want to explore our dataset further. We will extend our repeated-measures ANOVA by including the questionnaire data and different variables. One important aspect concerns the development of the intervention effects over time. Mindfulness requires constant training (Teasdale et al., 2000) or participants can be bored by listening to the same songs over and over (Madison and Schiölde, 2017). The question of whether different arousal and valence baselines before driving started have an impact generates further interest. If the participants already felt aroused or happy, the interventions may show limited effects. Additionally, we plan to conduct deep-dive interviews with our 10 participants to learn from their experience. They can provide insights into the interventions such as potential contexts when they are most efficient, possible hints how to improve them, or explanations about the effects while experiencing them. Finally, as mentioned in the introduction, we collected data on the driving behaviour and affective states of our 10 participants for 2 months before the intervention phase began. Hereby, we installed besides the mounted smartphone a driver-facing and a street-facing camera, a microphone, and a system to collect car sensor data. We believe that the correct timing of interventions is crucial for the successful deployment. Understanding the actual driver status determines when interventions can really help. Accordingly, we will use our collected data to predict driver affective states.

6 Conclusion

In this paper, we describe the current state of our research to bring psychotherapeutic interventions into the car and we share our initial findings. In this early phase, we contribute to current research in two ways. First, we explain in depth our study design and our reasoning on how to influence the affective states of drivers by transferring psychotherapeutic concepts into the vehicle. Second, with our preliminary results we can already show visible effects and demonstrate that IS can be used to reach people with our intervention concept in their daily lives. In the future, it is necessary to test the interventions with mentally ill subjects and disentangle the interventions effects further. However, since we designed this exploratory pilot study as the first of its kind, we will build on our findings in subsequent field and laboratory experiments. Our early results suggest that in-vehicle interventions rooted in well-established psychotherapeutic concepts positively improve the affective states of healthy drivers in the short-term.

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