SAFER Pre-studies

Final Report

Reference	*FP 10*
Project Title	Changing point of view: Exploring the impact of embodied cognition on automated driving design
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1 Contents

Summary

The goal with this pre-study was to explore new research avenues of Embodied Cognition to identify new design solutions for current design of human-machine interaction challenges in the design of semi-automated vehicles. Embodied cognition was presented in a format adopted to the automotive domain by means of three interactive workshops to bridge the gap between theory (and theorists) and practice (and practitioners).

The pre-study has: 1) identified the concepts from the domain of embodied cognition that can be of relevance for the automotive domain), 2) identified a set of implications that embodied cognition has for the automotive domain, and 3) developed a set of unified embodied design proposals for applying embodied cognition to autonomous vehicle design.

Changing point of view: Exploring the impact of embodied cognition on automated driving design

1. Background

In cognitive science there exist a number of contrasting and often conflicting paradigms on the nature of cognition and how cognition is to be studied. For a long time the pre-dominant paradigm was so called cognitivism which views cognition as information processing and the cognitive architecture like a computer, which we believe also influences the design of autonomous vehicles to a large extent. This pre-study aims to explore how the contrasting paradigm of embodied cognition (EC) can provide additional and alternative solutions for increased traffic safety in semi-automated vehicles. Work carried out in aviation, for example, showed how changing the perspective (e.g. the unit of analysis) from the individual pilot to the whole system-including the material and social environment of the entire cockpit–provided a new understanding and additional insights for the tasks and cognitive demands of a particular activity such as landing an airplane.

While still an open question, we suggest that it is useful to explore to what extent an EC approach can change the outcome of the analysis and consequently the design of (semi-automated)vehicles. For instance, there is a growing concern with (semi-)automated vehicles that drivers become “out-of-loop” and, that, as such, can lead to negative consequences. In this case, a non-EC analysis would perhaps focus on providing the driver with a better mental model of the system, while an EC analysis would instead consider that it as a lack of engagement and physical activity relating to the task. The point being is that bringing in a new perspective on what constitutes human cognition can provide new directions in terms of solutions. Also, a EC point of view would emphasize the situated and sensori-motoric nature of humans, emphasizing the “here and now” as well as how a particular physical embodiment affects cognition and control. Moreover, EC would consider that cognition is for action rather than viewing humans as passive and sequential information processors. An E standpoint would also consider thethe distributed nature of cognition in which the social and material environment is part of the cognitive system and, more importantly, humans often adapt to, as well as act to change, the social and material environment to support/ease perception and action.

2 Project set up

2.1 Purpose

The main purpose with this pre-study was to explore new research avenues of Embodied Cognition to identify new design solutions for current human-machine interaction challenges in the design of semi-automated vehicles. A deeper understanding of EC could generate alternative design solutions that ensure that the new technology in vehicles do neither work against the goal of Vision Zero nor the UN sustainability goals. While the main aim is to benefit the design of automated vehicles, the current and future work with (semi-) automated vehicles can also further inform and enhance current theories of EC. Today EC can be considered as a collection of ideas with a common core without a pre-defined methodology. By exploring EC for the automotive domain important contributions can be made. The pre-study targets in general the Road User Behavior research area in terms of the following:

- Ensure safe interactions between automated vehicles and other road users including vulnerable road users, by introducing an embodied and systemic perspective of drivers, vehicles, infrastructure and other road users.
- Develop and evaluate novel interaction principles, including "nudging", by exploring the EC approach into practical use cases.
- Define and measure user experience indicators related to safety, by exploring hedonic aspects like engagement as well as pragmatic aspects like driver response times.

2.2 Objectives

General objectives: The objectives of the pre-study were 1) to generate adopt knowledge of EC in a format suited for the automotive domain that bridges theory and practice. 2) to strengthen the competence of practitioners and also to build a network for competence of benefit for Sweden.

Objectives specific to Safer: The pre-study contributes by strategic knowledge creation, connecting a new constellation of partners to create unique perspectives on current relevant research and industrial problems to ensure the safety of future (semi-) automated vehicles. Knowledge that can be further developed in future projects

2.3 Project period

2021-04-01 – 2022-06-10

The project was extended due to the covid-pandemic to enable physical seminars at Safer.

2.4 Partners

The following companies/persons have been part of the pre-study. The workshops were planned together in the management team composed of Henrik Svensson (University of Skövde), Maria Klingegård (Folksam) and Jonas Andersson (RISE).

Jessica Lindblom was the original project leader and also took part in Workshop 1, but as she moved to the University of Uppsala Henrik Svensson assumed the role as project leader.

Participating organizations
Autoliv (two representatives)

Volvo Cars (one representative, originally supposed to be two but one intended representative changed employer before the project started and could not participate in the project, enquiries were made to her group at Volvo to find a replacement but was not successful)

Volvo GTT (one representative)

Volvo Construction Equipment (one representative)

Veoneer (one representative was part of the first workshop, but due to change of position within Veoneer, and changed employer during the project she could not participate in the other workshps)

3 Method and activities

A set of three (interactive) workshops with a group of practitioners from the automotive industry and representatives from academia with expertise in embodied cognition has been performed during the project. In the interactive workshops, the participants have been able to explore the concept of embodied cognition from their point of view under the guidance of the academia.

Three workshops were completed as described in the following section. The presentations and exercises are attached as appendices to this document.

WP1. What is embodied cognition

The workshop gave a broad introduction to the theories of embodied cognition and a selection of concept that specifically apply to the automotive industry and the challenges of designing (semi-) automated vehicles.

WP2. Applying the concepts

The second workshop applied embodied cognition to the automotive domain in a set of different use cases/design challenges (see e.g. Figure 1). We also discussed a number of predefined scenarios related to 1) driving behavior and 2) driver support systems (level 2 and level 4).

Figure 1: concept and application to AV

WP3. The first steps from theory to practice - design guidelines

The third workshop presented eight (8) proposals in the form of design considerations transforming theories of embodied cognition to autonomous vehicles (at different levels of autonomy). For each design consideration the participants answered a mentimeter survey

concerning the, novelty, relevance, applicability, and level of autonomy applicability. The survey served as a basis for discussion of the guidelines, as well as an initial validation.

4 Results and Deliverables

The core result of the pre-study is the discussions leading to the identification of the implications a change of perspective may have for the automotive domain as well as an illustration how it can be implemented in the format of design considerations. The project has thus fulfilled its goal to "generate additional knowledge about EC for the automotive domain that bridges theory and practice". More specifically, the following has been achieved:

- Identification of concepts from the domain of embodied cognition that can be relevant for automotive domain discussing embodied cognition.
- List of implications of embodied cognition for automotive domain (see Table 1 and Table 2)
- A set of unified embodied design considerations when applying embodied cognition to autonomous vehicle design

To increase the readability, the full result including the concepts, list of implications, the set of design considerations and proposals are described at the end of this report in an Appendix: Implications of changing perspective.

Based on the results, discussion are currently going on regarding applications and the formulization of a whitepaper.

5 Conclusions, Lessons Learnt and Next Steps

The current pre-study has made some progress in filling in the gap between theory and practice by selecting and adapting the concept of EC to the automotive domain raising important fundamental questions of cognition and thing that are taken for granted within the automotive domain. It is a difficult task as the embodied cognition theories are often at a rather high level of abstraction and there are also a large collection of different ideas and perspectives out of which we have only selected a few. Thus, more work is needed on the theoretical side to make the theories more concrete and specific. It was discussed that perhaps the design considerations need some more information as the embodied cognition concepts are sometimes difficult to understand.

The pre-study happened during the covid-19 pandemic, but it was still possible to conclude the pre-study albeit six months later than originally planned. However, the long periods of time that passed between each workshop was not helpful.

All participants have expressed an intention to continue the network formed, with an associated platform, and activities that may strengthen the Safer knowledge area Human Behavior.

6 Dissemination and Publications

The results of the pre-study was presented at the SAFER Thursday lunch & networking seminar September 8, 2022.

We plan to build an online repository of the relevant embodied cognition literature (including the design proposals) that can be made available to all Safer members. We also hope that the knowledge gained by the participants will spread also within their organizations.

As noted above, the intention is to discuss with the knowledge area Human Behavior on how our initiative can strengthen the knowledge area.

7 Acknowledgement

The project team would like to thank all the members of the participating organization for their contributions.

RISE contribution in this project has been made within the RE-ENGAGE project financed by Vinnova FFI (2020-02914).

8 Appendix: Implications of changing perspective

Your theoretical standpoint determines how you view the world, in this case, the driver and the vehicle. It determines what constitutes cognition and your take on the emergent interaction between the driver and the vehicle. In more detail, it determines (1) the view of the human driver (2) what is of interest when conducting studies, (3) how studies are performed (e.g. conditions and context included), (3) where studies happen, and (4) what design solutions are promoted.

The core of embodied cognition is the following (using a broad interpretation):

- the situated and sensori-motoric nature of humans, emphasizing the "here and now" as well as how a particular embodiment affects cognition and control,
- that cognition is for action rather than viewing humans as being passive and sequential information processors,
- the distributed nature of cognition in which the social and material environment of the human is part of the cognitive system and that humans often adapt to as well as act to change the social and material environment to support perception and action.

For more detailed expositions of embodied cognition the reader may consider the following papers (Anderson, 2003; Brooks, 1991; Chrisley & Ziemke, 2002; Clancey, 1997; Clark, 1997; Varela et al., 1991).

8.1 Practical implications of a change of perspective

There is a growing concern with (semi-)autonomous vehicles that drivers become "out-of-loop" and the negative consequences it may have (e.g. Boelhouwer et al., 2019) In this case, a non-embodied analysis would perhaps focus on providing the driver with a better mental model of the system, while an embodied cognition analysis would instead consider that it as a lack of engagement and physical activity relating to the task. The point being made here is that bringing in a new perspective on what constitutes human cognition will also provide new directions in terms of solutions. **Error! Reference source not found.** provides some examples of how embodied cognition concepts and theories might cause a change of perspective on the driving task and also on how to design vehicles at higher levels of autonomy. For example, the concept of sensorimotor coordination (Scheier et al., 1998) suggests that passive information processing may be limited and that it is useful and that biological organisms act to discover new perceptual information (sometimes called epistemic actions (Kirsh & Maglio, 1994)). Thus, the huge focus on processing camera images may also include the use of the lateral and longitudinal control actions that could be made to discover new patterns of information that is useful for the task at hand. Embodied cognition may also be used to put existing design guidelines in a new perspective as shown in Table 4. For example, the concept of anticipatory gaze teaches us that in normal goal related behavior, the eyes shift their attention to objects that will be acted upon in the future, but e.g., when the motor system is compromised or overloaded, perception cease to be

predictive (Donnarumma et al., 2017). Thus, this might be a way to increase the performance of in-cabin monitoring systems that are tracking eye-gaze. These concepts where the starting points for the design guidelines presented in the next section.

Table 1: Embodied concepts and their implications

Embodied concept	**Implication**
Sense-making Sensorimotor coordination	The driver is not a passive receiver of information. The driver/autonomous vehicle may act on the environment with the intent to generate new information.
Bodily, physical and social context	The car is always in a context, which means that the analysis of the behavior of a car needs to take many different aspects of different situations into consideration.
Situatedness (the emphasis on the continuous interaction between brain, body, and environment (physical and social))	Just as gesture, speech and neural activities form a integrated system that performs cognitive functions, the physical nature of the car or the other cars should not merely be seen as inputs to the central controller but together enact the behavior.
The whole body	Naturally, vision is given much attention, but the other modalities count and may be used to increase performance.
Dance-metaphor (information is not only transmitted but created together by social agents)	Information should not only be one way, but interactions may also be necessary to create information.

8.2 A set of embodied design proposals: from theory to practice

Through analysis of the literature on embodied cognition and the workshop discussions we derived eight (embodied cognition inspired) design consideratios for autonomous vehicles.

Each design considerations is currently structured as follows: a descriptive title, description of the proposal, theoretical motivation, and references to relevant literature

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on the topic. We have also added a scale indicating the novelty, applicability, usefulness where five blue cells correspond to "very high". The AD level scale indicates the SAE-level of autonomy at which the proposal could be applied. The scales are based on the judgment of 7 industry practitioners in the field. Grey filled cells for the AD level means that no consensus could be reached. There are two additional design guidelines (7 and 8) which have not yet been evaluated.

Besides the design considerations, we believe that one of the main take home messages from applying EC to the design of autonomous vehicle design is that EC broadens and changes the perspective of what the car is and does, giving rise not only to different symbols and modalities but also influences the designer's way of investigating the requirements before designing and also how to test one's design. However, in this report and the project, the more concrete contributions have been in the form of the following proposals, which show how embodied cognition could be applied to autonomous vehicle design.

Proposal #1: The whole body	Novelty	■	■	■		
	Applicability	■	■	■	■	
	Usefullness	■	■	■	■	
	AD level		■			
Description: Consider all sensory modalities for communication and interaction with/to the driver/passengers (auditory, visual, vestibular, taste, smell, tactile) to communicate with the driver.						
Theoretical motivation: Traditionally the visual sensory modality has been the focus of attention for research, but cognition is also shaped by other modalities (e.g. body posture may influence reaction time, e.g. depending on its compatibility with the current activity afforded by the situation)						
Literature: Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in Attitudes, Social Perception, and Emotion. Personality and Social Psychology Review, 9(3), 184–211. https://doi.org/10.1207/s15327957pspr0903_1						

Proposal #2: Whole body action	Novelty	■	■	■		
	Applicability	■	■	■		
	Usefullness	■	■	■	■	
	AD level		░	░	░	
Description: Consider all action modalities and whole body movement when designing car-driver/passenger interaction (i.e. not only button pressing/switching, but also, speech, gesture, gaze, whole body activity recognition).						
Theoretical motivation: Theoretical motivation: A) Cognitive agents are active and opportunistic using many different ways to achieve ones goals. B) Perception and action are not seperate but interdependent, e.g.,						

Proposal #2: Whole body action	Novelty					
	Applicability					
	Usefullness					
	AD level					

agents when engaged in goal directed tasks are predictively anticipating and looking towards the coming action relevant asepcts of the environment. C) Body posture may influence reaction time, e.g. depending on its compatibility with the current activity afforded by the situation, and bodily state may induce affective states and vice versa

Literature: Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in Attitudes, Social Perception, and Emotion. Personality and Social Psychology Review, 9(3), 184–211. https://doi.org/10.1207/s15327957pspr0903_1
Wilson, A., & Golonka, S. (2013). Embodied Cognition is Not What you Think it is. Frontiers in Psychology, 4, 58. https://doi.org/10.3389/fpsyg.2013.0005

Proposal #3: Active explorations	Novelty					
	Applicability					
	Usefullness					
	AD level					

Description: Allow active exploration of the driver/self-drive functions

Theoretical motivation: cognitive agents are not passive receivers of information, but actively explore their surroundings (with different types of action patterns) to get the relevant information from the environent. That is, cognition is not like scanning a camera-image.

Literature: Kirsh, D., & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. Cognitive Science, 18(4), 513–549. http://doi.org/10.1016/0364-0213(94)90007-8
Wilson, A., & Golonka, S. (2013). Embodied Cognition is Not What you Think it is. Frontiers in Psychology, 4, 58. https://doi.org/10.3389/fpsyg.2013.00058

Proposal #4: Allow off-loading						
	Novelty					
	Applicability					
	Usefullness					
	AD level					

Description: Provide ways of off-loading parts of the cognitive activities to the body, other actors, car or environment.

Theoretical motivation:Humans and some animals have evolved the ability to use different types of tools and we create this both over long periods of time and opportunistically.

Literature: Risko, E. F., & Gilbert, S. J. (2016). Cognitive Offloading. Trends in Cognitive Sciences, 20(9), 676–688. https://doi.org/10.1016/j.tics.2016.07.002
Susi, T., & Ziemke, T. (2005). On the subject of objects: Four views on object perception and tool use. TripleC: Communication, Capitalism & Critique. Open Access Journal for a Global Sustainable Information Society, 3(2), 6–19.

Proposal #5: Communication as dancing						
	Novelty					
	Applicability					
	Usefullness					
	AD level					

Description: Consider letting the driver/passenger and car mutually decide the context and learn from one another.

Theoretical motivation: Communication is not only the transmission of information, but information is created in the interactions between agents that together creates/determines the meaning.

Literature Clark, A. (1997). Being there: Putting brain, body, and world together again. MIT press. https://www.google.com/books?hl=en&lr=&id=i03NKy0ml1gC&oi=fnd&pg=PR11&dq=clark+being+there&ots=ZQ-_K1wnFI&sig=5Pi8sPsofink7q1lU8gH74IOs3Q
Bosch, K. van den, Schoonderwoerd, T., Blankendaal, R., & Neerincx, M. (2019). Six challenges for human-AI Co-learning. International Conference on Human-Computer Interaction, 572–589.

Proposal #6 : Prototyping for embodiment and situatedness	Novelty					
	Applicability					
	Usefullness					
	AD level					

Description: Consider using prototyping tools that allow for integration of several types of contextual factors, such as bodily, mental, physical and social context

Theoretical motivation: Humans cognition is embodied and situatuated in the sense that cognition at different levels and at different time frames changes with the context it is in, threre exists no cognition independent of context.

Literature: Rosenberger, R. (2012). Embodied technology and the dangers of using the phone while driving. Phenomenology and the Cognitive Sciences, 11(1), 79. https://doi.org/10.1007/s11097-011-9230-2
Wilson, A., & Golonka, S. (2013). Embodied Cognition is Not What you Think it is. Frontiers in Psychology, 4, 58. https://doi.org/10.3389/fpsyg.2013.00058

Proposal #7: Embodiment of the car	Novelty					
	Applicability					
	Usefullness					
	AD level					

Description: The embodiment of all support systems need to have high transparancy, the correct field composition (background/foreground) and a deep sedimentation

Theoretical motivation: Humans and some animals have evolved the ability to use different types of tools and we create this both over long periods of time and opportunistically. The car and the different functions of the car should be interpreted in the way tools can be in the foreground as things to be considered or residing in the background automatically performing its function.

Literature: Rosenberger, R. (2012). Embodied technology and the dangers of using the phone while driving. Phenomenology and the Cognitive Sciences, 11(1), 79. https://doi.org/10.1007/s11097-011-9230-2

Proposal #8: What is the unit of analysis	Novelty					
	Applicability					
	Usefullness					
	AD level					
Description: Consider enhancing the unit of analysis to span beyond the specific task						
Theoretical motivation: Actions and activities are not carried out in a vacuum, but are performed within a specific context (physical, social, cultural)						
Literature: Kaptelinin, V., Kuutti, K., & Bannon, L. (1995). Activity theory: Basic concepts and applications. International Conference on Human-Computer Interaction, 189–201. Suchman, L. A. (1987). Plans and Situated Actions. Cambride University Press.						