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A Cognitive Analysis of Truck Drivers' Right-hand Turns

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Abstract
This paper presents an investigation of truck drivers' performance during right-hand turns performed in intersections with traffic lights in order to elicit the truck drivers' domain, decision-making processes, and the strategies used while executing the turns. To gain knowledge about this, a truck driving instructor was interviewed, and four truck drivers were observed and interviewed. This resulted in a cognitive work analysis with the phases work domain analysis, control task analysis and strategies analysis. Through this study it is indicated that many different types of information are sought using several brief glances in mirrors, and the results shows how the front and near-zone mirrors were never used by the participants during the observed right-hand turns. Controlling the vehicle was found to be mainly automatic, whereas their focus is on the orientation about surroundings. Lastly, the drivers' behavior is discussed in relation to change blindness, confirmation bias and schemes.

Introduction
In February 2005, a meeting was held between the Traffic minister of Denmark and representatives of the country's major transportation organizations with the aim of initiating a collaborative research project on accidents between right-turning trucks and cyclists going straight ahead (Danish Transport Authority, 2014, p. 12). Also, a report on the analysis of 25 different accidents was published by the Accident Investigation Board for Road Traffic Denmark in 2006. In all 25 accidents it had been possible at some point for the driver to see the cyclist using his mirrors or windows. Based on this, they concluded that part of the problem stems from the drivers not orienting themselves sufficiently (Danish Road Traffic Accident Investigation Board, 2006, p. 10). The drivers themselves explained that they are thorough in their orientation, especially in cases with vulnerable road users nearby, yet they simply overlooked the cyclists involved in the accidents. They further proclaimed that executing a right-hand turn is a complex and demanding task because it requires attention to road layout, other road users, the physical dimensions of the truck etc., all of which is needed to adjust the maneuver both before and meanwhile turning (Danish Road Traffic Accident Investigation Board, 2006, p. 13, p. 24). The legacy of this work has led to increased awareness on right-hand turn accidents through campaigns and changes in regulations, which increased the required minimum to four specific mirrors on the right side of the truck, though blind spots still exist in parts of the right side and behind the truck

(Danish Transport Authority, 2014, p. 13, pp. 26-28; Danish Road Traffic Accident Investigation Board, 2006, p. 34, p. 65). Despite these efforts, right-hand turn accidents still happen on a relatively large scale (Danish Transport Authority, 2014, p. 3, p. 11).

Even though different research has been conducted on right-hand accidents internationally (European Cyclists' Federation, 2012; SWOV Institute for Road Safety Research, 2012), a more recent report from the Danish Road Safety Commission calls for research about the truck drivers' awareness and behavior in relation to mirrors, to get an overview of the traffic situation (Danish Transport Authority, 2014, p. 10). The present paper focuses on providing insight into exactly this. This project makes use of cognitive work analysis as described by Jenkins et al. (2008) based on the theoretical work of Rasmussen et al. (1994). This technique stems from a more general approach called cognitive task analysis that focuses not only on the physical step-by-step procedures, but also the cognitive processes connected to the physical tasks. It focuses on describing and representing cognition in relation to decision-making (Stanton et al., 2013, pp. 69-70).

Cognitive work analysis is a framework used to develop, evaluate, and analyze complex systems involving human interaction (Stanton et al., 2013, p. 70). It describes the flexibility of a system and focuses on eliciting the constraints imposed on subject matter experts by this system. These constraints define the possible activities within this system (Stanton et al., 2013, p. 70; Cornelissen et al., 2012, p. 363). Recently it has been applied to get an understanding of the interactions between different road users in traffic intersections (Cornelissen et al., 2013).

The cognitive work analysis is formed by five interconnected phases, each describing different types of constraints on the task. The method does not require the use of all phases, but can be adapted to the subject of interest and the scope of the project (Jenkins et al., 2008, pp. 16-18). This paper focuses on the first three phases of cognitive work analysis, which are work domain analysis, control task analysis and strategies analysis, since these are thought to give a fundamental understanding of the cognitive work of the truck driver and how the work domain is used. The work domain analysis will in the context of this project describe how and why the objects in the driver's cabin can be used to successfully perform a right-hand turn. The control task analysis will be used for evaluating what kind of information is needed by the truck drivers to do a right-hand turn, and how this information is used for decision-making. Lastly, the strategies analysis will be used to create a schema which can illustrate when specific objects are being used, for how long, and in what stages during different right-hand turns.

Method

In order to perform the work domain analysis, the control task analysis and the strategies analysis, two different kinds of subject matter experts were used. This was done because work domain analysis takes a theoretical approach to the possibilities of the truck environment (Jenkins et al., 2008, p. 19; Stanton et al., 2013, p. 74), while it is suggested in Jenkins et al. (2008, p. 17) to study work practices for creating the control task analysis. The strategies analysis was chosen to be based on observational data. The work domain analysis was constructed with the assistance of a truck-driving instructor. Field data for control task analysis and strategies analysis were obtained with the assistance of professional truck drivers. Two different data acquisition methods were used, as described in the following sections.

Work domain analysis

Design: Work domain analysis, as described by Jenkins et al. (2008, pp. 18-23), works on five different levels ranging from the actual physical objects at the lowest abstraction level, to the functional purpose of the system at the highest level (see Table I). These form the creation of a so-called abstraction hierarchy depicting the components of the individual level and how they are related to each other.

The analysis was conducted by interviewing a truck-driving instructor in the use case environment, i.e. a truck driver's cabin. The documentation of the abstraction hierarchy was done in collaboration between the instructor and the two interviewers, who had already set the overall functional purpose to be the performance of a right-hand turn.

Participants: The truck-driving instructor was 53 years old and had 33 years of experience with heavy vehicles. Before the interview, he was informed about the purpose of the study and interview, and how he was thought to be able to contribute. He was also informed about his rights to withdraw from the interview at any time, and the option of anonymity.

Apparatus: A truck cabin was used in the creation of the abstraction hierarchy. Pen and paper were used for writing and drawing, and the sound of the interview was recorded using Dictaphones.

Procedure: The interview started by having a warmup session in a classroom, in which general aspects of truck driving and the instructor's professional experience were discussed. After this, the focus changed to the work domain analysis, and the rest of the interview took place in a truck driver's cabin. First, the different levels in the hierarchy were described to the instructor and the top level was defined to be the performance of a right-hand turn. The instructor was then asked to point out the relevant physical objects in the truck in order for the lowest level to be filled. Each object was noted in a box on the paper by one of the interviewers, and each time an entry was made, it was shown to the instructor for his approval. Hereafter, the object-related processes were identified and connected to the physical objects by drawing lines, followed by the creation of the purpose-related functions level which was connected to the level below it. This was followed by identifying the values and priority measures based on the overall purpose, which were then connected to the functional purpose above them. After this, they were also connected to the purpose-related functions beneath them so that every element was connected to the corresponding levels above and below it.

When the entire abstraction hierarchy had been illustrated on paper, the instructor reconfirmed it, and after the interview was finished, an audit trail was made by use of the recordings. Furthermore, the abstraction hierarchy was digitized and reviewed by the use of the field data described in the next section. All this was done in order to increase the validity of the model (Lewis, 2009, p. 12).

Table I – The different layers in the abstraction hierarchy (Jenkins et al., 2008, excerpt from p. 20).

Level	***Description***
Functional purposes	*The purposes of the work system and the external constraints on its operation.*
Values and priority measures	*The criteria that the work system uses for measuring its progress towards the functional purposes.*
Purpose-related functions	*The general functions of the work system that is necessary for achieving the functional purposes.*
Object-related processes	*The functional capabilities and limitations of physical objects in the work system that enable the purpose-related functions.*
Physical objects	*The physical objects in the work system that afford the object-related processes.*

Control task analysis & strategies analysis

Design: In the data acquisition for control task analysis and strategies analysis, interviews were conducted based on observational data from video recordings of participants' right-hand turn performances in intersections controlled by traffic lights.

The observational data was acquired by the use of cameras placed in the truck cabin. One was placed in the upper left corner of the left window filming the surroundings of the truck and the use of objects in the driver's cabin, and one was placed in the upper right corner of the windscreen filming mainly the driver's movements, but also the traffic on the left of the truck. If possible, the driver would also wear eye tracker glasses, capable of filming the perspective of the wearer and measuring the focus point. If not, the truck drivers were asked to take a glance at each window and mirror in a specific order before driving, so that the video recordings of this could serve as a reference when deciding which window or mirror was used at any given time. All of these recordings were used in the interview for facilitating a conversation about the performance of the turns.

When conducting the interviews, a cognitive task analysis approach called critical decision method as described by Crandall et al. (2006, pp. 69-86) was applied. Critical decision method is used for learning about specific incidents by conducting interviews with subject matter experts. This is done in order to gain an understanding of why different decisions are made, which cognitive elements are essential in the decision-making process, and which thoughts are made during the process (Crandall et al., 2006, pp. 71-73). The method can be divided into four different parts as shown in Table II.

Table II – The four steps in critical decision method (Crandall et al., 2006, pp. 73-83).

Step	***Description***
Identifying the incident	*Choose the incident which should serve as the focal point.*
Timeline of incident	*Identify important events in the incident such as actions made, other possible actions and decision-making processes.*
Deepening into the incident	*Try to go beyond the facts and understand the expert's perception, goals, assessments, frustrations, uncertainties and considerations.*
"What if"-questions	*Get insight into the expert's knowledge and skills on the given subject by asking hypothetical questions.*

Videos recorded during the interviews formed the basis for constructing the control task analysis. In this paper the result of the analysis is a so-called decision ladder which maps the different levels in the decision-making in regards to the action (Jenkins et al., 2008, pp. 18-27). Both the driving videos and the interview videos were used in the process of creating the strategies analysis. The product of a strategies analysis has not yet been described as a generic tool and it thereby differs in its layout according to the context and purpose of the analysis, but was in this case used in order to model and illustrate the individual strategies used by the drivers in order to fulfill the right-hand turns (Jenkins et al., 2008, pp. 31-33).

Participants: The participants were required to have truck driving as a part of their profession and have at least five years of truck-driving experience. Four truck drivers in the age 39-60 (M 51, SD 8.98) participated. Their truck-driving experience ranged from 7 to 39 years (M 21, SD 13.66). Before the driving session, each truck driver was informed about the main purpose of this session as well as the later interview, and that they should try to act as naturally as possible. They were also informed about their rights to withdraw from the interview at any time, and the option of anonymity. In two cases the driver wore the eye tracker glasses, but in one of these the driver chose to take them off due to him feeling uncomfortable.

Apparatus: Two GoPro HERO3+ Black Edition cameras were used for recording the driving sessions, which also required access to the drivers' truck cabins. One of these cameras was also used for recording the later interview and a Dictaphone was used for ensuring the data acquisition in case of camera failures. Tobii Glasses 1 Eye Tracker was used for recording the perspective of the driver. An Asus U37J laptop running Tobii Studio software was used for exporting eye-tracker data into a video file. The driving session videos were synchronized on an Apple MacBook Air 13.3" laptop using homemade software, which allowed for all videos to be displayed simultaneously during the interview. Paper and pen were used in the creation of timelines. A questionnaire was given to each participant containing questions about the driver's regular driving habits and how these differ from the observed, if so.

Procedure: Before the driving session with each participant, one or two of the authors placed the cameras in the driver's cabin. In collaboration with the driver it was decided whether the session would take place during the driver's regular work route or on a special route designed to contain at least two right-hand turns in intersections controlled by traffic lights.

Table III – External conditions during the observed turns based solely of footage from the turns.

Turn conditions		***P1: 1***	***P1: 2***	***P2: 1***	***P2: 2***	***P3: 1***	***P3: 2***	***P4: 1***	***P4: 2***
Recessed stop line		✓			✓				
Cycle lane		✓		✓	✓	✓	✓	✓	✓
Cars in front of truck in same lane		✓		✓		✓			
Stops at red light		✓		✓		✓	✓		✓
Cyclist(s) at the right side of the truck	*Cyclist(s) waiting to cross the intersection*				✓		✓		
	Cyclist(s) passing the truck			✓					
	Truck passing the cyclist(s)								
Stops during turn to orientate									
Pedestrians to the right of the truck in the intersection		✓	✓						
Vehicle at the left side of the truck		✓	✓*	✓					✓

*The intersection is placed in narrow streets, and the vehicle passing the truck on the left is an oncoming bus.

After the driving session, a semi-structured interview was prepared by the authors based on the critical decision method procedure. First, the incidents were identified by handpicking two of the turns recorded, according to them having to be right-hand turns in intersections controlled by traffic lights. When the two turns had been chosen, the videos containing these were synchronized. Next, one timeline per turn, consisting of written accounts of every observed event as well as corresponding timetags, was created based on the videos. In Table III the external conditions of the observed turns are shown, where each turn is defined by the driver ID (e.g. P1) and their turn number.

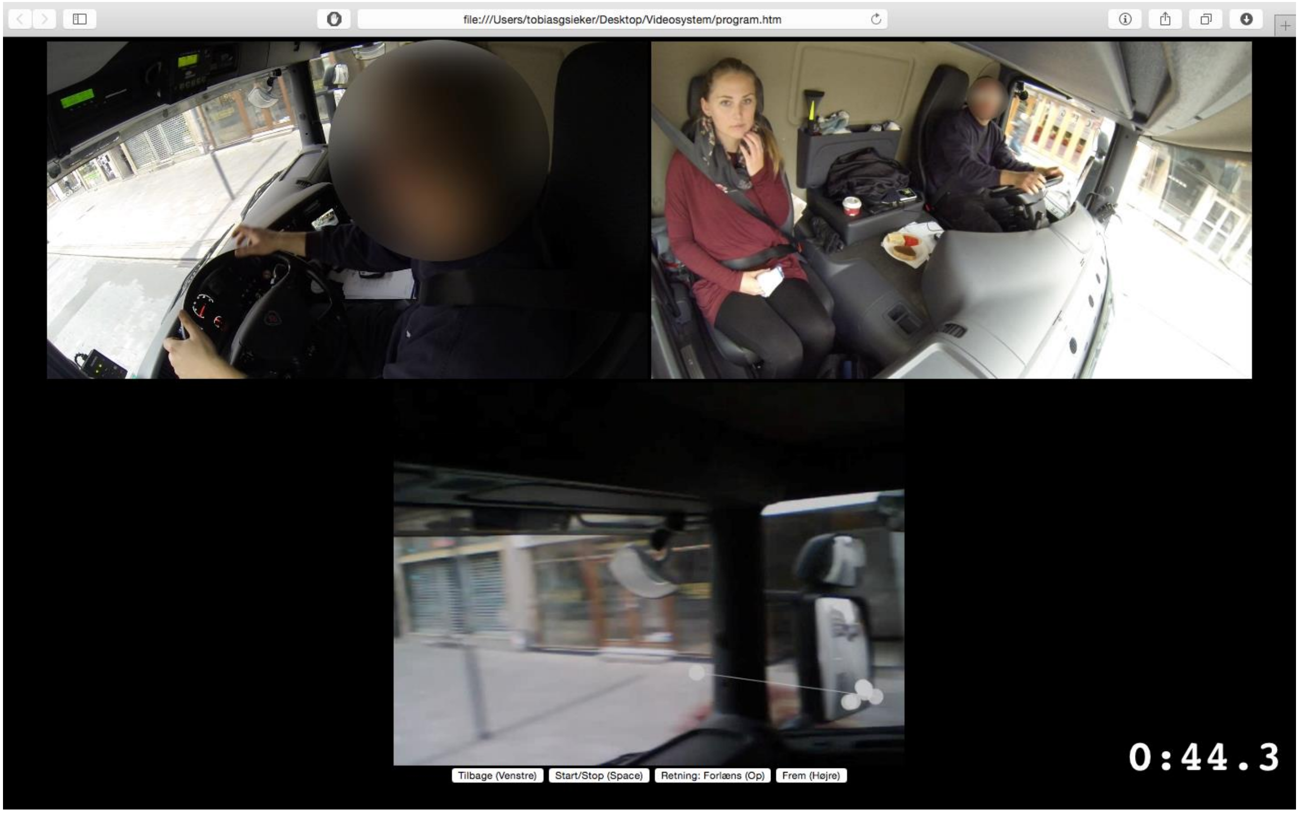

Fig. 1 - Example of the interface used during the interviews.

Later the same day, the driver was first given the questionnaire after which the interview session took place. This started by watching the videos of the first turn and verifying the starting point of this turn together with the driver in order to increase the validity (Lewis, 2009, p. 12). After this, the critical decision method was followed by asking questions about each timeline incident in order to get an understanding of the meaning of the actions performed during the turns. The driver's verification of the timeline was acquired simultane-ously. The same procedure was followed for the second turn. The interface used to play back the videos during these parts of the interview session is shown in Fig. 1, in this case including the eye tracker video. After having gone through every action in both turns, hypothetical questions were asked in order to get a more detailed understanding. Lastly, information from the questionnaire was evaluated and used to facilitate concluding questions about the validity of the observations. All of the interviews were recorded on video for further use.

Data processing was done separately for the control task analysis and the strategies analysis. To create the decision ladder in the control task analysis, explanations from the interview videos were decomposed into table data according to the levels in the decision ladder. The decomposition process was performed by two of the authors at a time, who discussed how to classify the data, in order to increase the validity (Hesse-Biber and Leavy, 2011, p. 51; Lewis, 2009, p. 11). In order to create the strategies analysis diagram, another de-composition was made, in which each interaction with an object was noted along with time points explaining when the interaction started and ended. This data was derived from the driving videos. Also, for each action in these videos, an explanation was sought in the interview videos.

Explanatory psychological theories

Three psychological theories will be considered in the context of the results. One theory relates to change blindness; the perceptual phenomenon of not being able to detect changes in a visual stimulus. A change occurring in two pictures immediately following each other is likely to be discovered, because this change is perceived as an optical motion. If the pictures are not immediately following each other, or if large amounts of motion happen, it is possible to overlook the change (Bruce et al., 2003, pp. 414-415). The other theory relates to confirmation bias; the theory that people tend to seek information that confirms their existing beliefs and what they expect to find (Nickerson, 1998, pp. 175-177). Lastly, Vaa's idea that drivers act either consciously or unconsciously based on emotions induced by external events in order to achieve or maintain the best possible feeling, will also be discussed (Vaa, 2013, pp. 105-108).

Results

Work domain analysis

The abstraction hierarchy obtained from the work domain analysis is depicted in Fig. 2, which shows that 11 out of 16 physical objects can be used when trying to avoid hitting cyclists. Eight of these are used for seeking information about cyclists and mopeds, and the other three are used to reduce the truck speed. The amount of physical objects potentially used for seeking information about cyclists and mopeds indicates that there are many different places to gain knowledge about these. Contrary to this, the reduction of speed can only be achieved through the use of three different objects, allowing fewer ways to perform this task. Every object-related process to the left of the information search for cyclist and mopeds regards different other information searches. These are heavily connected to the purpose related functions, especially compared to the object-related processes to the right, which all concern the controlling of the truck. Of course, this model depicts all objects, which can potentially be utilized, and not whether they are actually used. One truck driver mentioned that everything related to driving the truck is pure routine, and not something he thinks about, while he has to be constantly aware of his orientation about other road users.

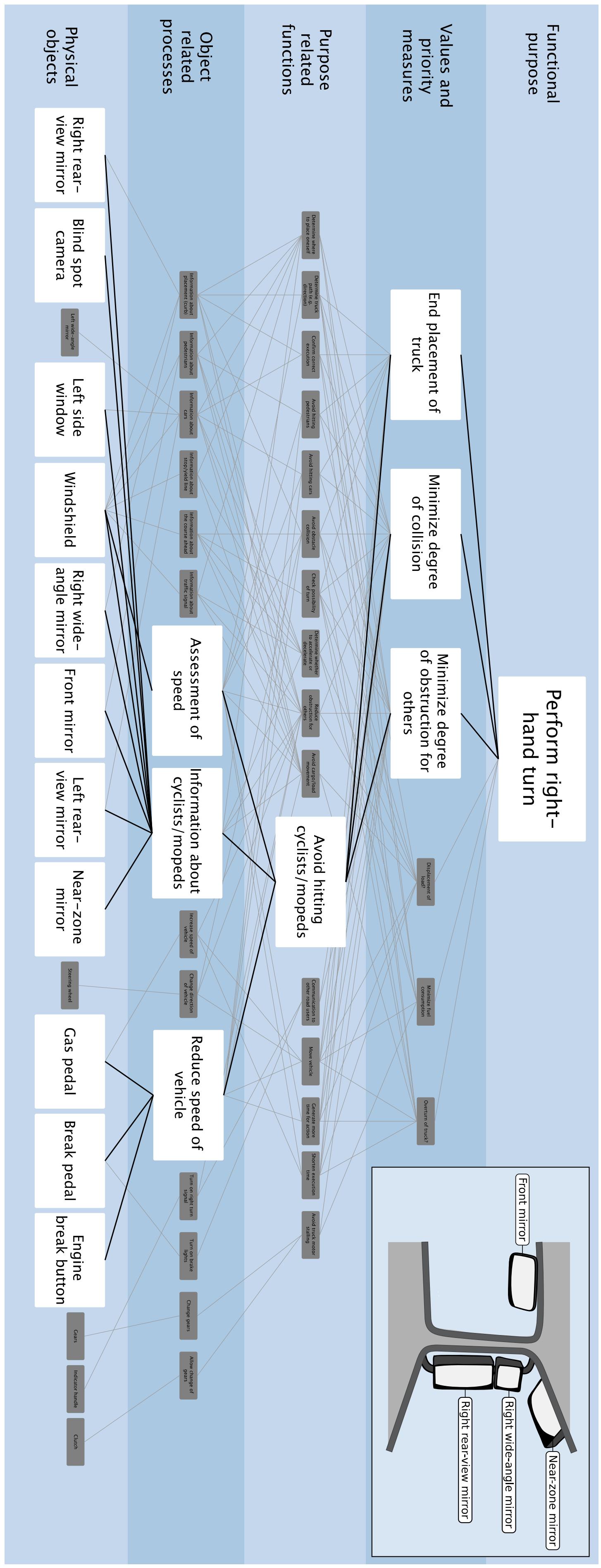

Fig. 2 - The abstraction hierarchy with boxes regarding the avoidance of hitting cyclists and mopeds in white.

Looking at the values and priority measures in connection to not hitting cyclists and mopeds (Fig. 2), it shows that this is not only a question of avoiding collision, but also regards the end placement of the truck, and the degree to which it is obstructing others. These measures are connected to several different purpose-related functions. All of the values and priority measures are heavily connected to the purpose-related functions, suggesting that multiple factors are potentially involved when determining how successfully a given turn has been executed. If all of these factors influence the success of the turn, the task could turn out to be rather complex.

Control task analysis

The decision ladder shown in Fig. 3 is the result of the control task analysis, and is divided into different stages in the decision-making process. The overall goal is shown in the top of the model and is in this context the execution of a right-hand turn. For this to be successful, it has to be performed within the constraints, being something that somehow affects the actions. This analysis indicates that the constraints mainly concern executing the turn safely, and doing this as fluently as possible. The alert regards the event that initiates the upcoming action, and in this study the spotting of the intersection is the only alert that has been elicited. In the next stage, information is sought from the surroundings in order for the driver to gain knowledge about specific elements, in this case mostly information about other road users and the characteristics of the road. The system states are then derived from two or more pieces of information. These states focus primarily on whether something will intervene with the truck's path. Based on these states, the driver predicts the consequences of different actions in order to investigate his options of changing the system states. Here the driver only has six different options for altering the system states. By evaluating how these options correspond to the constraints of the goal in relation to the system states, the constraints are prioritized, their consequences predicted, and the options evaluated once again. This loop continues until the driver is satisfied with the consequences of his prioritization. In the following stage, options are chosen and according to this, singular tasks are defined. Only four tasks are possible, whereas three are about controlling the vehicle, and one is about information gathering. Finally, these tasks are put into procedures, some concerning the execution of the turn and some doing it as fluently as possible (Jenkins et al., 2008, p. 28; Jenkins et al., 2010, pp. 139-140).

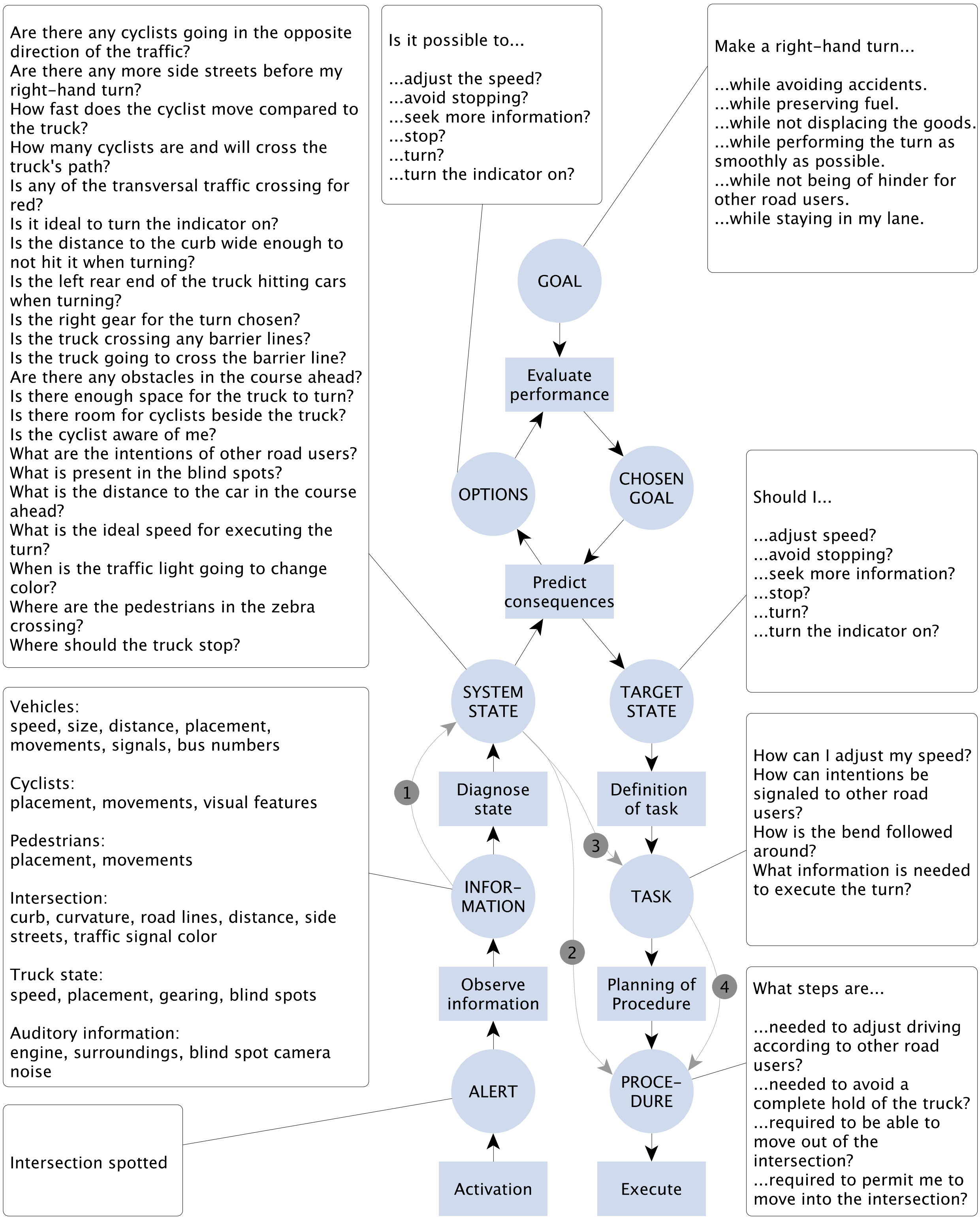

Fig. 3 - Decision ladder illustrating the decision-making of a right-hand turn. Each square illustrates a data-processing activity, while the circles symbolize the resultant states of knowledge. The boxes connected to the states contain the questions and constraints related to each of these states. Leaps are illustrated by numbered arrows.

Novice users are expected to follow the decision ladder in a sequential manner, while experts make rule-based shortcuts through the ladder, based on former experience (Jenkins et al., 2010, p. 136). The drivers, in general, had trouble explaining what information they sought, suggesting that these processes in those cases happen at an unconscious level. This indicates that the drivers are not aware of what information they use to determine system states, and that this is done automatically, i.e. without any conscious processing. This is illustrated in Fig. 3 by leap one.

In some cases, the drivers explained how they based only on their understanding of the situation jump to the execution of the task without further processing, for instance when turning after having concluded, that there are no cyclists to be aware of. This suggests a leap from system state directly to procedure indicated by leap two in the model. Another leap related to this one goes between the system state and the task, for instance in cases where the driver needs to wait for something to change in the system state before being able to execute the turn, e.g. when waiting for pedestrians to get out of the zebra crossing before continuing the execution. Arrow number three illustrates this. The last leap noted is from task to procedure symbolized by arrow number four. This leap stems from the drivers indicating that they do not think about the actual driving, but that their focus is on orientation. Thereby, it is indicated that the steering of the truck during a right-hand turn is something the drivers know like the back of their hand, or as one participant put it:

> *"If I had to think about my driving, I would never get my job done."*

Strategies analysis

Based on the individual strategies used in all eight observed turns, several patterns occur. The windshield and the right-rear view mirror are the information displays most in use during the entire turn.

In the preparation phase the focus was mostly on the windshield, which was used in the determination of a number of system states depending on the circumstances. This is consistent with the work domain analysis, which shows how the windshield affords multiple different information searches. The left rear-view mirror was mainly used once early in this phase, for seeking out information about vehicles behind and to the left of the truck. This was done both since the end of the truck swings out during the turn and might hit passing vehicles, and because the drivers have to be more aware of passing vehicles. The right rearview mirror was used for short glances to gather information about vulnerable road users. When getting closer to the turning phase, the focus mainly switched between the right-rear view mirror and the windshield, with the duration of the windshield glances generally getting shorter, and the frequency of information searches in the right rearview mirror increasing.

In the turning phase, most of the time was used looking in the right rear-view mirror. At this point the main information sought concerned the truck's placement in relation to the curb in order to avoid hitting it. The rear-view mirror was combined with brief glances through the windshield. Some used the left rear-view mirror during this phase for seeking information about the placement of the back end. When the drivers started to straighten up, the focus was once again changed to the windshield for estimating placement and to look for upcoming obstacles.

Not all drivers made use of the wide-angle mirrors, but if used, they were often used in combination with the rearview mirrors for seeking information about vulnerable road users. There were no observations involving the use of the near-zone or front mirrors, and one driver stated that he only uses them, if he is already aware of the presence of several cyclists, or if he has limited space around him.

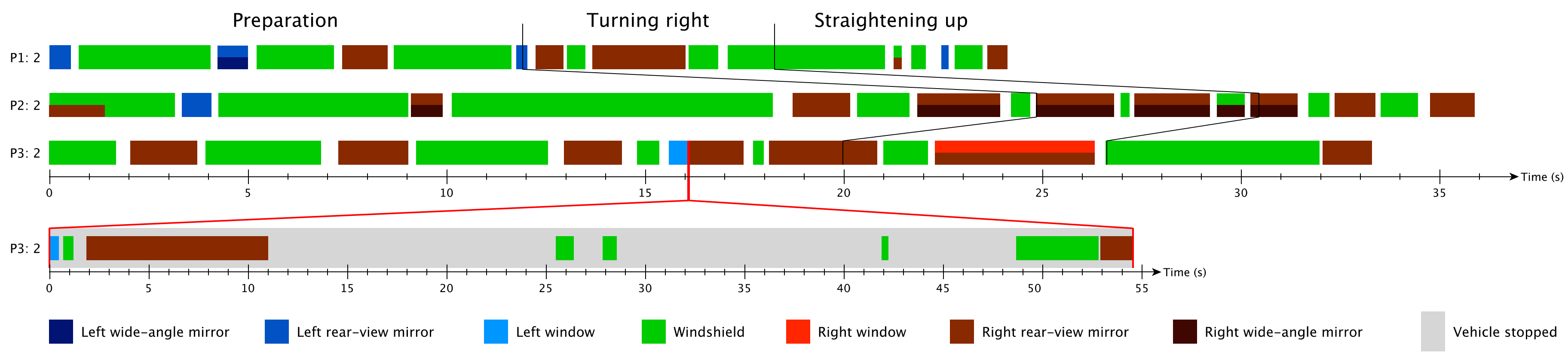

Fig. 4 - Strategies analysis diagram featuring three representative turns, in which no cars were in front of the driver, and vulnerable road users were present.

In Fig. 4, the general patterns observed have been attempted to be depicted by schematizing three different turns. These turns have been chosen, because they have in common that no cars were in front of the driver, and vulnerable road users were present in the intersection. Also, they were performed by three different drivers. The other turns showed fairly similar patterns in the strategies used. Each row in the figure depicts a turn and is labeled by the driver's id and the turn number. The turns have been split into three phases to illustrate the progression, which have been determined by the use of the steering wheel, so that the turning right phase begins when the steering wheel is turned right, and the straightening up phase begins afterwards, when the steering wheel is turned left. Everything before the turning right phase is noted as being preparation for the turn. The figure shows usage of windows and mirrors as boxes in different lengths according to the duration of the glances. These are color coded according to the key in the bottom of the figure. Participant number three's second turn differed from the others, because he had to wait for a red light to change. This waiting period is shown underneath the three turns.

Most general patterns are also found in Fig. 4, especially the switching between windshield and right rear-view mirror, though some differences occur in driver behavior. Participant number one stands out because of more frequent use of the left rear-view mirror throughout the turn, which was also the case in his first turn. Conversely, participant number three did not use this mirror at all. Also, the use of the right wide-angle mirror is different between participant number two and the two others depicted, since he often used this in combination with the right rear-view mirror.

During the interview with participant number three, he explained about the depicted turn, that he already knew how to proceed based on his surroundings when he had to stop and wait for the red light to change. In other words, he had already defined his task based on the system state, and was merely waiting for the light change in order to proceed with his actions. Because of this, he only made small glances during his waiting time to ensure that the system state did not change in a way that would affect his upcoming actions. This further supports the behavior shown in leap three in the decision ladder.

Questionnaires

All participants informed that they felt comfortable about the situation, and that the observed driving corresponds to normal driving. One participant stated that he usually does not speak to anyone during his driving. Even though the others did not mention this, they usually also drive alone, but during the interviews they all explained, that the settings did not affect the driving. However, in regards to the questions about their driving habits, all of them stated that they usually listen to the radio, which none of them did during the sessions. Also, one driver was used to smoking during his driving, which he did not do, and others talked about their driving and awareness during the driving sessions.

The changes in behavior might not directly affect their turn performances, but it indicates that the driving sessions have been somewhat affected by the presence of the observers. This suspicion increased since one driver explained that in the days leading up to the driving session and the interview he got more aware of his driving, and analyzed how he performed his right-hand turns. Other drivers could in the interviews, hours after the driving sessions, accurately remember the clothing of cyclists before seeing them on tape. This further increased the suspicion even though it is unknown whether this degree of awareness is normal.

Psychological explanation

As seen in Fig. 4, the drivers' visual attention switches a lot between different information displays, especially during the turn of the steering wheel. Furthermore, the mirrors in each side of the cabin requires the driver to shift focus from one side to the other, and the elements displayed in the mirrors can be quite small, taking up little space in the visual field. It could be considered whether this affects the drivers' abilities to detect changes in the environment. Taking change blindness into account in relation to this, if a driver looks in one mirror, looks in his windshield, and then again looks in the same mirror, he might not be able to detect changes in the environment. If the changes happen out of his focus area, it gets even harder to detect them (Bruce et al., 2003, pp. 414-416).

The actions performed by a driver depend on his determined system states, and in case he overlooks information, the system states created might be misleading. Because of confirmation bias, this gets problematic, since the driver might try to search for information, which supports these wrong system states instead of looking for information, which contradicts them. An example of this is the driver stating, that his use of the front and near-zone mirrors only happened, if he already knew about the presence of several cyclists, or if he were driving in a narrow street. Hereby, in case he misinterprets the situation and overlooks cyclists in the first place, he would presumably not be aware of them later on, even if they were visible in these mirrors.

In the work domain analysis seen in Fig. 2 the driving instructor emphasizes that the different mirrors can be used both to achieve information about cyclists and in order to minimize the degree of collision. However, in our observations none of the drivers make use of the front and near-zone mirrors, even though these might had been helpful in providing information about the presence of cyclists. This behavior might be explained by schemes already established by the drivers. According to Vaa (2013, pp. 104-108), the automatization of actions happens as a result of humans always trying to achieve the best possible feeling in any situation. As the driver gets more experienced, he will learn how to react to certain situations based on this former experience, since the emotional outcome he achieves based on the consequences of his actions will act as a reinforcing stimulus which in the end helps building schemes of automated behavior. This might explain why the truck drivers does not use the front and near-zone mirrors in the first place, since they might often have experienced how they have not helped them gaining more information about cyclists nearby. The absence of the positive, rewarding emotion they otherwise would have got from gaining this desired information instead might then have taught them not to look in these mirrors unless they already know that they will likely be helpful in determining the future actions. This could indicate that the action has been economized in a way which does not involve the front and near-zone mirrors, at least to some extent.

In our observations it seems like the drivers might also have formed individual schemes concerning the use of the left rear-view mirror. In this case, two drivers, participants number two and four, use this mirror once or twice in the observed right-hand turns, whereas participant number one uses it continuously throughout the turns and participant number three does not use it at all in any of the observed turns. That participant number one and participant number three differ is rather interesting since these are both driving in the same city center in similar intersections. The behavior of participant number one could suggest that he at some point has experienced positive, rewarding emotions when making use of the left rear-view mirror. He also explains, that his need for orientation might be related to his background in the military. In contrast to this, participant number three's behavior suggests a lack of experiencing sufficient reward from using this mirror which might have made him neglect it in right-hand turn situation. Of course, other factors should be considered when trying to account for the differences observed e.g. participant number three is by far the most experienced driver and his truck is also smaller than the others'. Additionally, it is shown in Table III, that the external conditions were not the same during the observed turns which might as well explain the difference in behavior. The drivers themselves explain that their usage of the left mirror(s) depends on three factors: the size of the truck, the narrowness of the turn and how close the cars are behind them. These three factors are related to ensuring that there is enough space around the truck backend for the turn to be made without colliding with any obstacles.

Separately these phenomena might cause problems, and could also occur in combination. For instance, if the driver has been looking for cyclists while approaching the intersection, and counted three of these, he might not notice an additional one appearing further behind him, due to change blindness in combination with him not expecting to see more than three cyclists. When the first three cyclists have passed him, and his system state suggests, that there are no more cyclists to be aware of, he might proceed with the turn, as learned from former experience, now using his mirrors for focusing on the curb, and potentially overlooks the fourth cyclist.

Discussion

When addressing the validity of the results, it has to be considered to what extent the participants were affected by the authors. In the driving sessions, the drivers' knowledge about being observed might have had an impact on their behavior, and under the interviews, including the one with the driving instructor, the authors could have unwillingly influenced the answers given by the participants. Thus, the participants might have unconsciously pleased the authors, meaning that they have given the answers assumed to be desired. For instance, one of the participants himself stated that this study was mainly about cyclists, even though it was presented as a study about the performance of right-hand turns. Based on this, he might have adjusted his interview answers accordingly, so that the cyclists were described to be of higher importance than they would otherwise be. The focus of the work domain analysis was solely on the internal environment, i.e. the driver's cabin. Based on the results, it seems that the external environment also takes part in facilitating the turn, for instance by the curvature of the intersection and the color of the traffic lights. These aspects are not to be found in the abstraction hierarchy. In the use of the control task analysis and the strategies analysis, the right-hand turn was examined out of context from the rest of the driving. This might not be a problem, but it indirectly assumes that it makes sense to study it as an isolated part. However, it might be that the drivers think about the performance of the turn as an inherent part of the overall driving task, which is continuous and not split into different smaller parts. An example of this is that the drivers in some cases talked about, how they used information gathered prior to the defined starting points of the turns, e.g. by having already determined the number of cyclists in the previous intersection.

To make the interview sessions more efficient, it was chosen to let the truck drivers answer the questions forming both the control task analysis and the strategies analysis at once using the critical decision method, in contrast to splitting up the interview in two parts, each focusing on one of these analyses. By using this approach, time was saved and the fatigue of the drivers made less likely, but it comes with the risk of not getting completely in depth in both analyses. Because of this, it has to be considered whether the full potential of the analyses was utilized, especially because the authors have no prior experience in using the models presented. Critical decision method takes a retrospective approach, thereby making it possible for the drivers to make use of reasoning in order to explain their actions. By doing this, it is risked that the single actions have been ascribed more value than what they are really worth, so that trivial actions suddenly seem more relevant.

When examining the results in relation to the theory of change blindness, it seems that the great amount of different information searches makes it possible to overlook changes in the environment. Furthermore, based on confirmation bias, it might be hard to change an already existing system state, even though it could be incorrectly perceived. Thereby, in order to prevent right-hand turn accidents, a solution might be to somehow hinder the making of wrong assumptions about the states of the system. To make this solution more robust, it could also account for the problem of change blindness, maybe by avoiding the need for information searches in multiple different places.

Conclusion

The aim of this paper was to conduct a cognitive analysis of truck driver's awareness during a right-hand turn in an intersection controlled by traffic lights. This was done through a work domain analysis, a control task analysis, and a strategies analysis, which showed, that many different types of information is sought during the turn, but also that multiple patterns exist, especially in regards to the use of the windshield and the right rear-view mirror. Most information searches about other road users take place while approaching the intersection, whereas the focus is mainly on the placement of the truck during the actual turn. Furthermore, it was found that the driving part of the task is more or less automatic, while the more demanding part is the investigation of the surroundings and how these might impact the performance of the turn.

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