Humans' expectations of automatic vehicle guidance in cooperative situations: Modeling with Naturalistic Decision Behavior

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Abstract: With the introduction of automatic vehicle guidance (AV), mixed traffic scenarios between automatically and manually guided vehicles are to be expected, at least at the beginning. Thereby, situations which afford a cooperative interaction between human drivers and AV are of particular interest. An approach to understand human decisions in cooperative situations is the Natural Decision Making (NDM). It describes how experts make decisions in complex and uncertain conditions. An example for the NDM approach is the "Recognition Primed Decision Model" (RPD) of Klein (2008) which we applied for this study. With the help of a "Recognition Module" it divides the relevant factors of a decision into "Actions", "Expectations", "Relevant cues" and "Goals". As a method to investigate expectations in particular, an online questionnaire was used in which the respondents (N = 87) were presented various cooperative situations and asked about expectations regarding AV. As a result, the relationships between goal and actions as well as actions and expectations could be examined in more detail. Furthermore, the results were compared with another online survey (Imbsweiler et al., 2018) in which the expectations of human road users were examined. We conclude with recommendations on the behavior that needs to be taken into account when investigating cooperative behavior in the future.

Keywords: Natural Decision Making, Cooperation, Expectation, Automated Vehicle Guidance

1. Theoretical Background

Cooperative situations in road traffic have come to the fore with the probable introduction of automatic vehicle guidance and the associated mixed traffic. For mixed inner-city traffic, published research covering relevant scenarios is currently rare. Potential relevant scenarios for inner-city traffic could be equal narrow passages with an obstacle on each side, T-crossing scenarios where two road users turn left and one road user wants to drive straight ahead, or X-crossing scenarios where all four road users arrive simultaneously. All scenarios have in common that a deadlock arises and that, according to StVO § 11 (3), the road users have to negotiate who is allowed to drive first. The situations are described in more detail in Imbsweiler et al. (2016, 2017a,b, 2018a). In order to negotiate priority or right of way, road users have various communication signals at their disposal de Ceunynck et al. (2013).

One of the questions to be addressed regarding cooperation between road users is how to model cooperation. Imbsweiler et al. (2018) have chosen the modelling approach of Natural Decision Making by Klein (2008). This approach is shown in Figure 1. It makes use of the Recognition Primed Decision Model (RPD) (Klein, 2009) to find out how experts address problems.

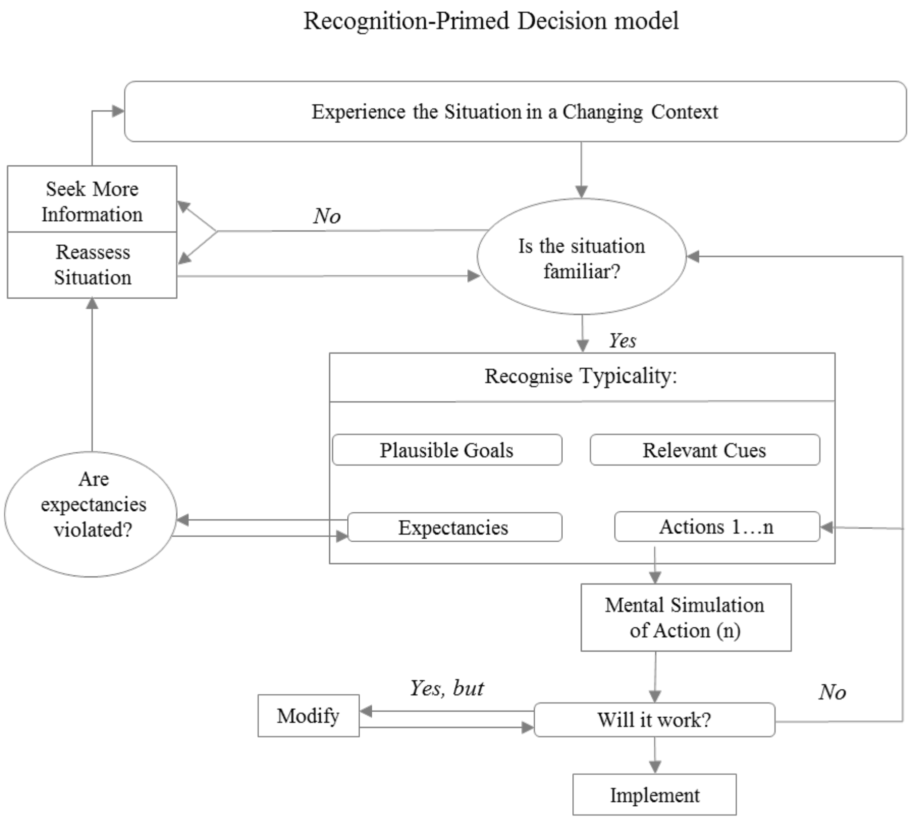

Figure 1: *Recognition Primed Decision Model by Klein (2009).*

According to de Ceunynck et al. (2013), in traffic scenarios a distinction can be made between implicit communication signals (braking, accelerating, stopping and maintaining speed) and explicit signals (hand gestures, direction indicators, horn and flasher). The “Recognition Module” divides the decision process into "Actions", "Expectations", "Relevant cues", and "Goals". In an online survey conducted by Imbsweiler, Stoll, Ruesch, Baumann & Deml (2018b) this approach was chosen to derive design recommendations for automated vehicles. For this purpose the study was oriented to a study by Björklund and Åberg (2005), who investigated yielding behavior in right of way intersections with a questionnaire.
The study by Imbsweiler et al. (2018b) dealt with the expectations of human road users in cooperative situations. The question which expectations human road users have of **AVs** in inner-city cooperative situations was not investigated.

Based on the preliminary work, the relationship between **Expectations** and **Actions** will be examined more closely and whether the relation can be categorized. If this is the case, the question arises whether it can be used to make predictions in relation to the **Goal**.

2. Method

2.1 Respondents

With the help of the software LimeSurvey, an online survey with *N* = 87 respondents (*n* = 31 female, *n* = 56 male) was conducted. The mean age was 26.46 (*SD* = 7.61).

2.2 Procedure and Material

The above mentioned scenarios of the T-junction, X-junction, narrow passage, and three other interactive scenarios were queried. The other tree situations were clearly regulated but interaction is required depending on the initial situation. These were a one-sided narrow passage and regarding Björklund and Åberg (2005) two scenarios with priority to the right, each with a wide and a narrow lane and two lanes of equal width. The situations were presented randomly and by means of an animated picture. After each situation it was determined with whom the respondents would communicate, at which position in the order of travel they intended to leave the situation, with which communication signs they would make contact (implicit: accelerate, brake, hold speed, stop; explicit: horn, direction indicator, flasher or hand gesture) as well as which behavior they expected from the cooperation partner. At the end of the questionnaire demographic data was acquired (see Figure 2).

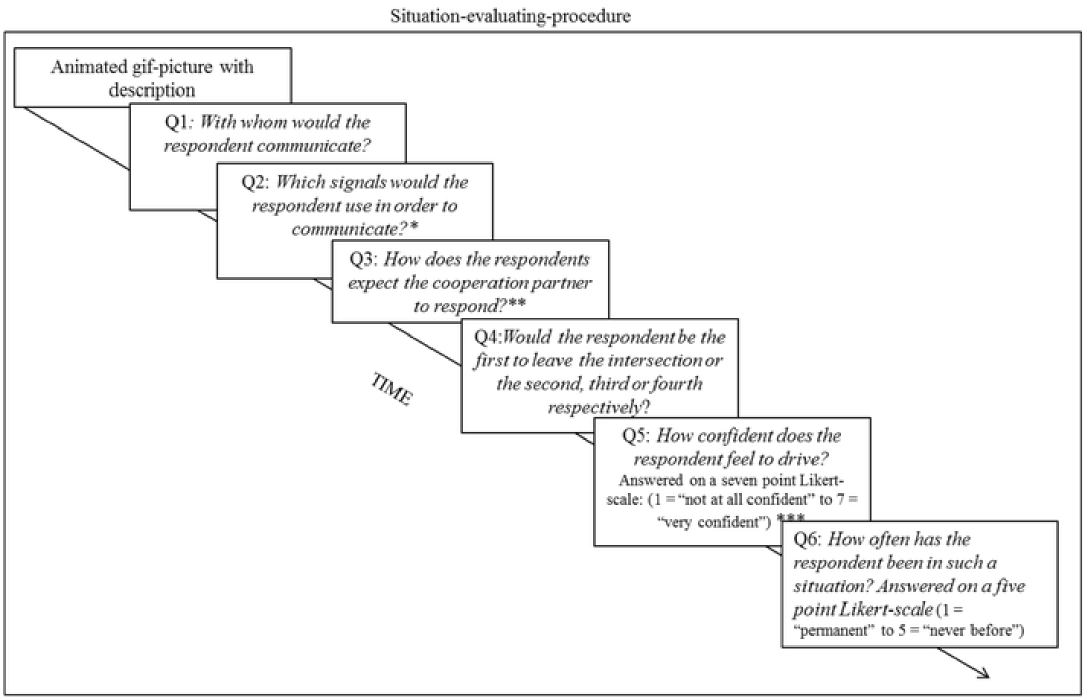

Figure 2: *Procedure of the survey. See Imbsweiler et al. (2018b).*

2.3 Data-analysis

For the relation between actions and expectations, a fuzzy-cluster approach according to Hartinger et al. (2011) was chosen and evaluated with R-Studio Version 1.0.143 and the package "cluster" by Maechler, Rousseeuw, Struyf, Hubert, and Hornik (2017). The cluster analysis considered the answers to the expectations and actions. This approach was chosen because it involves binary categorical data and has already been applied successfully in earlier work. The approach is described in more detail in Imbsweiler et al. (2018a, 2018b).

The second question was analyzed using a logistic regression. The goal to drive first versus to drive second was defined as the criterion. As predictors the identified clusters were entered into the analysis. This means that a mean value averaged by the number of variables per cluster is formed and acts as a predictor.

3. Results

The advantage of a fuzzy cluster is that there is an assignment coefficient for each variable, so that the variables can be assigned to a cluster but at the same time it can also be considered to which clusters the variable could still belong. Based on the preliminary work by Imbsweiler et al. (2018b), four clusters can be assumed for the new data of the study. These are shown in Figure 3. It is possible to classify the chosen actions and the expected actions of the AV. For cluster 1 and 3 the respondents expect offensive signals and would act defensively. For cluster 3 and 4 the respondents expect defensive actions and would act offensively.

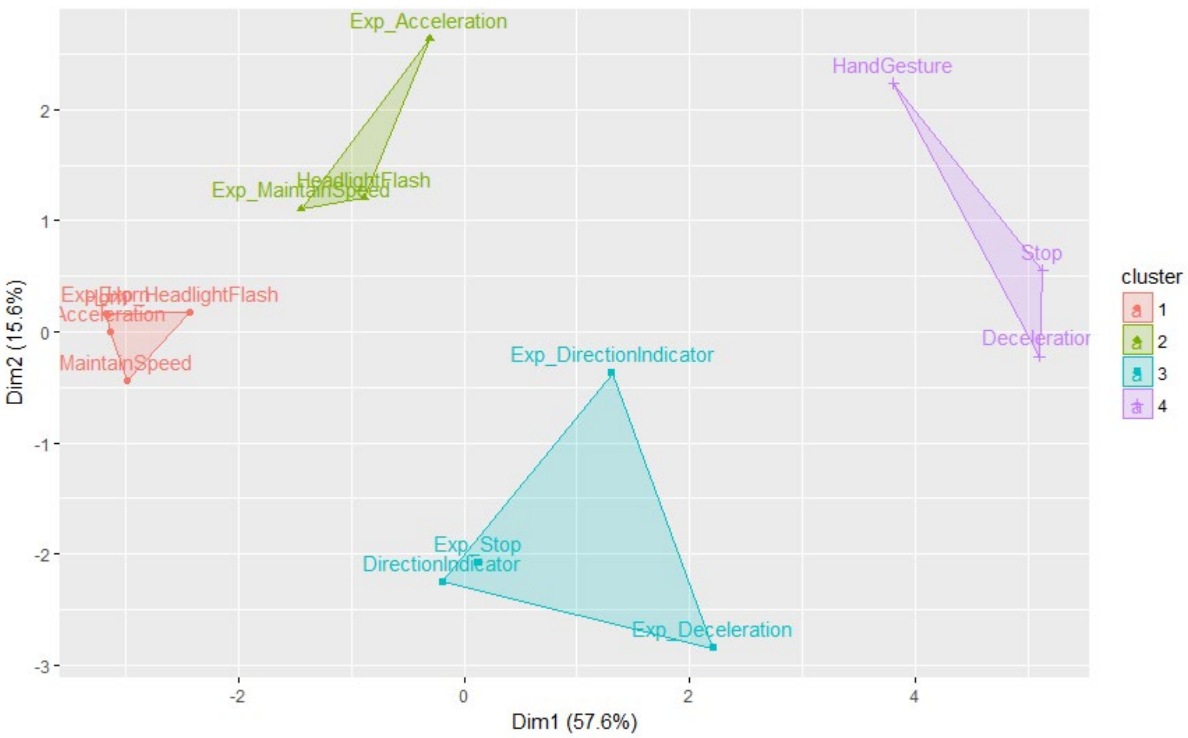

Figure 3: *Fuzzy-Clustering of the goals and expectancies with four clusters as preparation for the logistic regression. Exp = Expectancies.*

In a next step the logistic regression was used to test whether the clusters were able to predict the probability that the first or the second driving position would be used (see table 1). The chosen and expected actions are able to predict the order of driving which is related to the goals. It is possible to see with which actions AVs could solve a situation and which behavior can be expected from the human cooperation partner. The pseudo measures are to be assessed as very high.

Table 1: *Logistic regression with the clusters of the Fuzzy-Analysis as predictors and the goal as criterion. Driven first = 0 and driven second = 1.*

	95% CI for odds ratio			
	B (SE)	Lower	Odds Ratio	Upper
2:(intercept)	1.804** (0.918)	0.006	6.076	3.603
Cluster1	-1.107*** (0.280)	-1656	0.331	-0.558
Cluster2	1.091*** (0.338)	0.428	2.976	1.753
Cluster3	-0.629*** (0.147)	-0.917	0.533	-0.342
Cluster4	0.633*** (0.168)	0.303	1.883	0.963

Note: McFadden-Pseudo² = .228; Observations 430; Log Likelihood -148.65; Akaike Inf. Crit. 1,307.305, ***p <.01, **p < .05

In an open format, the respondents were asked what kind of solution and expectations they had of an AV in general. The categories formed are shown in Figure 4. It becomes clear that the respondents expect an AV to behave defensively and communicate this.

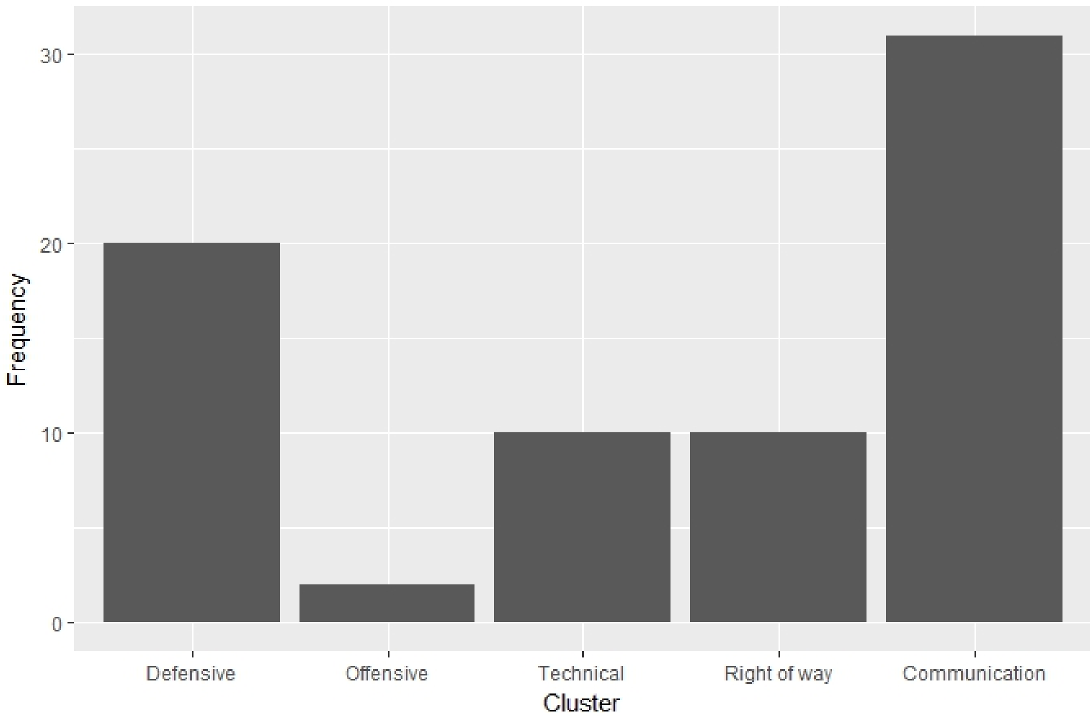

Figure 4: *Frequency of the answers reagrding the identified clusters.*

4. Discussion

It can be summarized that with the help of the NDM it is possible to model cooperation processes. The connections between expectations and actions could be uncovered. With Cluster 1 and Cluster 2 it could be shown that an offensive action is expected on a headlamp flasher. Cluster 4, on the other hand, is a cluster consisting only of actions. The connections to the other variables had to be shortened due to the visual representation and can be understood better by the help of the coefficients. Furthermore, these clusters can predict the driving sequence.

The methodical approach is also interesting. The formation of a sum normalized to the size of the cluster seems to be a mean of evaluating categorical data. This must be checked again with a larger data set and other approaches of data-analysis.

The open query shows that most respondents assume that an autonomous vehicle behaves defensively and that it will communicate with them.

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