Relationships between Oncoming Traffic Intensity, Subjective Predictions about Oncoming Traffic, and Intentions to Overtake

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Abstract

One of the main sources of fatal accidents on German rural roads is overtaking despite risky scenarios. It was examined whether predictions about the future volume of oncoming traffic – based on the volume of oncoming traffic just experienced – influences the decision to overtake in these circumstances. The predictive framework model served as rational for the investigation of predictions as a possible mediator in the connection between oncoming traffic volume and overtaking intention. For the purpose of the study, 37 students (25 female) completed five runs with varying levels of oncoming traffic in a driving simulator. Each route ended with a traffic situation in which an overtaking maneuver would be potentially risky. After each trip, participants overtaking intention and the prediction of future oncoming traffic were documented with a questionnaire. No clear link could be found between different amounts of oncoming traffic and overtaking intention. Most of the test drivers indicated a positive intention to overtake regardless of the experimental condition. The predicted oncoming traffic ranged between none and no more than a moderate amount and was therefore estimated to be rather low across all conditions. Furthermore, it turned out that the assessment of future oncoming traffic is influenced by the level of oncoming traffic just experienced. However, the predictions made about oncoming traffic in the near future showed no mediating influence on the relationship between experienced oncoming traffic and overtaking intention. The results cannot make a substantial contribution to a deeper understanding of risky overtaking decisions. Rather, the observations suggest that the cognitive processes during such traffic scenarios and maneuvers should be examined in more fragmented approaches.

Keywords: overtaking decision; risky overtaking; simulator study; traffic intensity; predictive framework model.

1. Introduction

In Germany, overtaking maneuvers occupy the third place among the causes of death in car accidents [1] and about 40 % of fatal overtaking accidents are related to overtaking despite oncoming traffic [2]. This leads to the question why drivers decide to overtake in potentially risky situations and there is a need for investigation to better understand the causes and mechanisms responsible for this risky driving behavior.

Research in this context has extensively examined infrastructural and situational factors. For instance, the assumption is that roads with generous lateral space and generous lines offer better sight and swerve-possibilities and therefore lead to an increase of overtaking maneuvers [3]. As a result, a tendency towards more risky overtaking maneuvers is developed with an increase in accident frequency and severity [4]. Furthermore, it is assumed that an increased traffic volume in the on-going direction or a slow-moving lead vehicle leads to an increase of overtaking maneuvers, since drivers have the ambition to drive at the highest possible speed, respectively [4, 5]. The critical fact is that a dense traffic volume increases the desire to overtake while at the same time, the occurrence of large and safe overtaking gaps can decrease due to a dense traffic volume in the opposing lane as well [5, 6]. In addition, a big leading vehicle, e. g. a van or truck, can increase the amount of misjudgments about sufficient overtaking gaps because the sight distance may be limited [5, 6]. The aforementioned parameters may facilitate the development of a so-called overtaking pressure, defined as the difference between desired and

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realized passings [3]. With no overtaking option available, the overtaking pressure raises and the desire to overtake may contribute to critical overtaking judgements and decisions [5, 7].

A crucial question is to which extent drivers collect data about the intensity of oncoming traffic and whether they use these data to develop adequate predictions about oncoming traffic in a forthcoming overtaking decision. For this approach, the *predictive framework model* provides a theoretical ground for investigation. According to this model, a *hierarchical generative model* is predicting sensory input in advance instead of processing incoming sensory input stage by stage as late as it is available [8-10]. Specifically, the brain tries to estimate via top-down processes how states of the world, events and the own body will cause sensory input and then predicts the most likely upcoming sensory input. The basis for the estimation are statistical regularities captured over time. The predicted inputs are continuously compared with the actually received sensory inputs and only deviations (*prediction errors)* are processed to generate precise and accurate predictions resulting in minimal discrepancy in the future [8-11]. However, in unknown situations or a high likelihood of unexpected events, *prediction precision* can be completely off target, since the basis for predictions is little to not available [9, 11]. A low prediction precision and a high degree of *subjective uncertainty* are the result, increasing the probability for prediction errors [9, 11].

As described above, it is already known that a high volume of oncoming traffic is supposed to reduce the number of overtaking maneuvers due to less appropriate overtaking gaps [4, 5]. However, it has been barely investigated how a traffic situation recently experienced affects decisions that require an assessment of a future traffic situation when no visual information about oncoming traffic is available (e. g. the road ahead is not visible). It is conceivable that drivers are using information they have previously encountered, namely, the *intensity of oncoming traffic* in the preceding minutes. Forecasts based on this information may be used to evaluate future risks. If a driver has not encountered any oncoming traffic for an extended period of time, he could assume that no oncoming traffic has to be expected even during overtaking.

Therefore, this study aimed to investigate the direct influence of different intensity levels of oncoming traffic on the *overtaking intention* in risky situations. In addition, it was examined whether *predictions*, as assumed in the predictive framework model, serve as a potential mediating factor in the decision process regarding these overtaking maneuvers. It can be assumed that drivers shape predictions according to the level of oncoming traffic recently experienced and that these predictions affect the attitude towards risky overtaking maneuvers.

2. Methodology

To investigate the relationship between the intensity of oncoming traffic, individually derived traffic volume expectations, and overtaking decisions, a simulator experiment was conducted. 37 participants (25 female), recruited from the student population of the Leuphana University, Lüneburg, took part in the study. The age range was between 18 and 28 years (M = 21.61, SD = 2.50) and all had a valid driving license for a minimum duration of 1 year and a maximum of 11 years (M = 4.06, SD = 2.57).

The virtual roadway was presented as a 180-degree simulation via three video projectors. Rear-view and side mirrors were visible to the drivers. The oncoming traffic traveled at a speed of 15 km/h and created a life-like feeling of movement. The spacings between the vehicles varied, as in real road traffic. The track structure imitated a German type EKL 3 road with an allowed speed limit of 70 km/h.

The driving scenario was realized with 5 intensity levels of oncoming traffic: none vs. little – 5 vehicles/min vs. moderate – 10 vehicles/min vs. high – 15 vehicles/min vs. very high – 20 vehicles/min., presented in an randomized order. The full driving course consisted of 3 sections with with a total average driving time of 4 minutes. Segment 1 (*manipulation*) was an easy-to-drive road with spacious, slight curves and no other traffic present on the own lane. In the second segment (*pressure*) overtaking was prohibited and drivers swiftly approached a slow-moving truck travelling ahead on the same lane until it restricted the view to the road ahead to trigger the need for overtaking. The track changed into a long right-hand bend in the last segment *(decision)*. The bend was poorly visible due to trees and the truck driving ahead. At short distance before the end, overtaking bans were lifted and drivers faced a traffic situation in which an overtaking maneuver would be potentially risky. The scenario ended about three seconds later. Across all segments, verbal audio announcements informed the test person at intervals of 30 seconds about the remaining time to reach an airport early enough – a fictitious time limit constructed to provoke the need to overtake.

During each simulation run, speed data and all initiated and completed overtaking maneuvers were recorded. Main dependent variables and covariates were measured by questionnaires conducted in German language. After passing through each condition, participants had to complete a questionnaire to rate the probability that they will overtake the lead vehicle on a response scale ranged from *1: not at all* to *5: very certain*. Additonally, *subjective certainty* of the probability assessment was adressed (scale: *1: not certain* to *5: very certain)*. The third item reflected the *need to overtake* with a response scale ranging from *1: not prominent* to *5: very prominent*. The possible mediation variable *prediction about oncoming traffic* was measured through estimations of oncoming traffic regarding the scenario just experienced (scale: *1: none* to *5: very high*), reflecting the traffic intensity levels of the driving scenes. The complete research process took approximately 42 minutes per participant.

3. Analysis and Results

To analyze the effects of the experimental manipulation (oncoming traffic intensity) on the dependent variable intention to overtake, mean values for each condition were further analyzed (Figure 1). The data could not revealed a substantial correlation (r = -.12, *n.s.*) between these two variables. A repeated measures ANOVA revealed a significant difference between measurements ($F(4, 140) = 3.26$, $p = .01$) but a Bonferroni-adjusted post-hoc analysis ($p = .017$) showed that the effect is only due to the difference between condition 1 (none) and condition 4 (high), 0.64, 95%-CI[0.08, 1.20]. No other comparison showed significant differences (all $p \geq .06$). The assumption that the intention to overtake differs between all experimental conditions can therefore not be confirmed.

An analysis of the relationship between the predicted and actual intensity of oncoming traffic indicate a moderate correlation ($r = .32$, $p < .01$.). A repeated measures ANOVA with a Huynh-Feldt correction revealed a statistically significant difference between measurements, $F(3.38, 118.57) = 15.87$, $p < .001$. Four significant differences could be identified by a Bonferroni-adjusted post-hoc analysis. The effect is due to the fact that only the condition without oncoming traffic differs from all other intensity conditions. No further significant contrasts could have been identified (all $p = 1.00$).

Finally, it was examined whether the prediction about oncoming traffic is mediating the effect from intensity of oncoming traffic on the intention to overtake. The only significant result was the regression intensity on prediction with $\beta = .321$, $p < .001$. No mediation could be found in the connection between intensity of oncoming traffic and intention to overtake (Figure 2). A bootstrap analysis (number of bootstrap samples: 1000) showed no indirect significant effect (-0.24, 95 %-CI[-0.08, 0.23]).

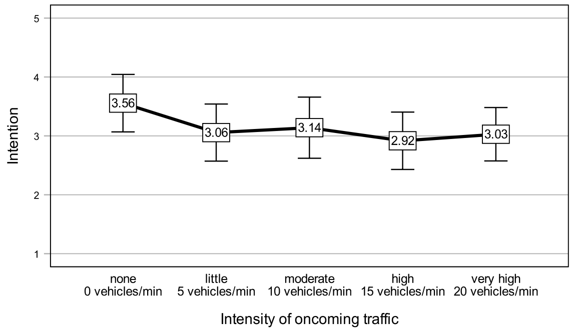

Figure 1: Mean values for intention to overtake in the five experimental conditions. Error bars indicate a 95 % confidence interval. N = 36.

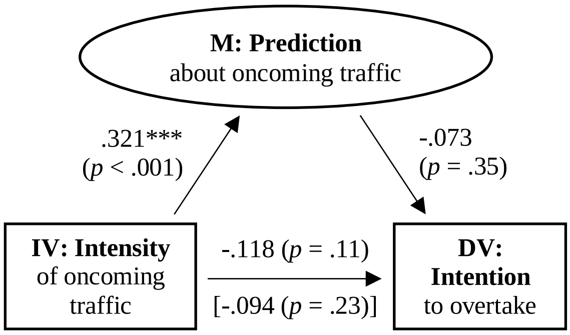

Figure 2: Single results of mediation analyses. β = standardized coefficient. Confidence interval = 95 %. N = 180.

4. Discussion

The assumption that drivers show a decreasing overtaking intention with increasing oncoming traffic intensity could not be supported in its entirety. Only if drivers were not exposed to oncoming traffic at all they showed a statistically higher overtaking intention compared with the situation, in which a high amount of oncoming traffic was present. It is important to note that the overtaking intention always ranged in the upper half of the given scale, just above the rating of *maybe*, regardless of the present oncoming traffic volume. These results contradict the above-mentioned research results [4, 5], according to which the volume of oncoming traffic certainly has an influence on the decision to overtake. The prediction ratings concerning potential future oncoming traffic ranged only between low and moderate. Statistically, the same amount of oncoming traffic was predicted in all situations where oncoming traffic was present. Thus, this study did not show the hoped-for effect that the predictions, made in the predictive process, can be derived from situational factors; respectively can be manipulated by these factors. Although the oncoming traffic intensity proved to be a significant, but not particularly meaningful, indicator for the predicted traffic level in the mediation analysis, the assumption that predictions ultimately influence the coherence between oncoming traffic and the decision to overtake cannot be confirmed. Despite that, directional tendencies can be identified in the data that are analogous to the assumptions made beforehand. Participants showed a higher intention to overtake in conditions with a lower level of oncoming traffic and if more oncoming traffic was predicted, the subjects showed a lower overtaking intention.

It became apparent that the certainty about the intention to overtake was consistently rated as *fairly certain*. The predictive framework model implies that the subjective certainty should be comparably high in well-known or exhaustively monitored situations and in addition, certainty is a factor that is strongly subjective and thus embedded in the person. Eventually, it was discovered that people who had a higher overtaking intention also rated it with a higher certainty rating. Furthermore, the participants reported a rather high need for overtaking, which did not differ significantly between the levels of oncoming traffic.

The present results suggest that drivers were not able to perceive and process the oncoming traffic intensity in a differentiated way. Therefore, it should also be considered that drivers are only forming a dichotomous rudimentary image of the oncoming traffic based on the all-or-nothing principle: present vs. not present oncoming traffic. This raises the question of whether at all, and if so then which differences are still perceived by drivers in relevant situational factors and which are included in their decision-making. Findings regarding the ability to differentiate these critical factors could ultimately contribute to a better understanding of human error and an implementation in safety training.

5. Conclusions

The basic assumption of this study was that drivers overtake in road sections that are not sufficiently visible if they have encountered none or just a little oncoming traffic for a longer period of time. Drivers simply assume that there will be no oncoming traffic even at the time of overtaking. Unfortunately, the study cannot make a substantial contribution to a better understanding of the underlying processes and the question of why drivers overtake frequently in risky or unpredictable situations. Instead, this study showed exactly this phenomenon to its full extent. From a strict risk-averse and reason-based perspective, all drivers should have indicated a very low to non-existent overtaking intention. Since they could not fully oversee the relevant route section ahead, it was impossible to make reliable estimations about the future oncoming traffic. Despite this, participants showed a high overtaking intention above all expectations, which was almost independent of the intensity of oncoming traffic.

This suggests that overtaking procedures should be increasingly addressed in driving training and, above all, actively practiced. In order to specifically address the risky decision making, driving schools should raise the student driver's awareness in this regard and teach and train safety-promoting processes. This includes, for example, learning to draw attention to oncoming traffic as well as how to monitor it even when they are not in overtaking situations. However, monitoring processes are necessary but not sufficient – above all, student drivers should learn to derive a differentiated representation of the oncoming traffic situation from their monitoring. This could enable them to maintain and use a concrete internal statistic, rather than having to rely on all-or-nothing judgments about the occurrence of oncoming traffic.

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