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# When does alcohol hurt? A driving simulator study

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ABSTRACT

World-wide, alcohol is still a major cause of traffic accidents. The dose-related accident risk function has been found in a large number of risk studies. A plethora of laboratory studies has examined the effect of alcohol with regard to different information processing capabilities of drivers. Summarizing the results, alcohol effects occur at lower blood alcohol concentrations (BAC) the more complex the tasks get. However, in contrast, typical alcohol-related crashes are frequently single vehicle crashes but not so often crashes in complex situations like at intersections. It may be that the subjective assessment of the traffic situation and the adaptation of behavior under the influence of alcohol plays a major role in accident causation.

In order to examine this hypothesis, two driving simulator studies were conducted at a target BAC of 0.5 g/l comparing two (alcohol vs. placebo; n = 48, Experiment 1) and three (sober, placebo and alcohol; n = 63, Experiment 2) groups of subjects in two critical scenarios. The first scenario was a seemingly easy traffic situation and was supposed to lead to a relaxed driving behavior under alcohol. The second scenario involved a complex intersection situation where especially drivers under the influence of alcohol should try to concentrate and compensate their experienced alcohol effects. In all scenarios, a critical object appeared suddenly and the driver had to react fast in order to prevent a (simulated) accident.

Overall, the results support the hypothesis. Accidents were more frequent for alcohol drivers as compared to placebo/sober drivers in the easy scenario, but not the complex one. The initial speed of the driver when entering the scenario seems to play a major role in the accident causation. Drivers under the influence of alcohol seem to lower their speed in complex scenarios, possibly to thus counteract alcohol effects. In seemingly easy scenarios this does not seem necessary for them and the arousing effect of alcohol may contribute to driving faster. The results are summarized in a model of alcohol-related crashes. Further in-depth analyses of real crashes would be an interesting next step to further corroborate this model.

## 1. Introduction

Although alcohol-related accidents have been declining since the seventies, in Germany in 2015 still 4.3% of all accidents with injuries or fatalities involve a drunken driver (Statistisches Bundesamt, 2016). For fatalities alone, the percentage is 7.4%. Thus, alcohol-related accidents seem to be the more severe accidents. But how does alcohol work and in which manner does it lead to accidents?

Studies on the alcohol-related accident risk (e.g., Holcomb, 1938; McCarroll and Haddon, 1962; Borkenstein et al., 1964, 1974; Perrine et al., 1971; Farris et al., 1976; McLean and Holubowycz, 1981; Zador et al., 2000; Krüger and Vollrath, 2004; Blomberg et al., 2009) have shown a very similar picture: Up to a BAC of about 0.5 g/l alcohol does not substantially alter accident risk. At BACs larger than 0.5 g/l accident risk begins to increase exponentially. Thus, there seems to be some kind of a threshold before a detrimental effect in form of an increased accident risk occurs. After that threshold, an increase in dose seems to multiply these effects.

For a better understanding of these patterns and the effects of alcohol, driving simulator studies have been examining driving-related performance under the influence of alcohol for almost four decades now (for an overview, Creaser et al., 2011). In a recent review of these studies, Irwin et al. (2017) showed that measures describing the basic control processes when driving are sensitive to the effects of alcohol, like SDLP (standard deviation of lane position) or the number of lane crossings (both measures of lateral control) or mean and standard deviation of speed as measures of longitudinal control. In contrast, (simulated) crashes do not seem to be as sensitive as these more basic aspects of driving performance (see below).

A second approach examines different aspects of human performance in experiments under the influence of alcohol to better understand how alcohol works to deteriorate task performance, like, for

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example, in driving. In these kinds of studies, the general consensus seems to be that automated processes are less sensitive to alcohol-induced impairment than controlled processes (for example, Krüger, 1993; Holloway, 1995; Moskowitz and Fiorentino, 2000; Schnabel, 2011; Berthelon and Gineyt, 2013; Martin et al., 2013). The more complex the task examined, the more likely it seems to be that alcohol negatively influences performance in this task.

However, understanding how this leads to accidents and what part of alcohol's effect is responsible for this is still largely unexplored. As the overview of Christoforou et al., (2012) shows, even in driving simulator studies on the effect of alcohol, only 8 of 18 studies looked at possible crashes. Similarly, in their review about the sensitivity of different measures (including driving simulator studies), Jongen et al. (2016) found 48 driving simulator studies with alcohol. Only 9 of these examined the number of accidents (Banks et al., 2004; Howard et al., 2007; Vakulin et al., 2007; Marczinski et al., 2008; Moskowitz et al., 2000; Quillian et al., 1999; Ronen et al., 2008, 2010; Berthelon and Gineyt, 2014). The results of these studies are quite mixed. An increase of reaction time due to alcohol may lead to (simulated) crashes if obstacles like slow cars suddenly appear on the road and require a fast braking reaction of the driver. This increase may be a direct effect of alcohol but could also be due to a reduced attention caused by alcohol or other factors which are not further examined in these studies. Moreover, the effects are not consistently found in all studies. Jongen et al. (2016) even conclude "…number of accidents …were found insensitive to the effects of alcohol in most studies" (p. 40). Thus, although accident risk studies clearly show an increased accident risk due to alcohol, driving simulator experiments fail to provide causal explanation of why this is the case. Although the studies can clearly show how alcohol changes different aspects of driving behavior (for a summary, see Moskowitz and Fiorentino, 2000; Irwin et al., 2017), the description of how this leads to accidents remains unclear.

Contributing to this difficulty is the finding that some people seem to be able to hide to some extent to the detrimental effects of alcohol. This phenomenon has been described as alcohol tolerance. In their overview, Chesher and Greeley (1992) described astonishing abilities of highly intoxicated drivers to act inconspicuously and to seem to be sober to outside observers. This kind of compensatory behavior could also be important in driving under the influence of alcohol. In order to examine and explain this compensatory behavior, Vogel-Sprott (1992) has shown that an active learning process may play a crucial role, enabling people to systematically counteract the effects of alcohol if this is advantageous for them (Vogel-Sprott, 1992). In particular, if drivers expect in a certain driving situation that alcohol may lead to negative consequences (like losing your license in a police control), compensating alcohol effects and acting sober is reinforced if they succeed in doing so and the police does not notice the intoxication (negative reinforcement). This model can also be transferred to the case of alcohol-related accidents: If drivers fear in a certain situation that their intoxication may lead to an accident, they can try to prevent this by actively compensating alcohol's effects. If they succeed in avoiding the accident, this may serve as a reinforcement for compensation. Accordingly, although their driving abilities may be impaired, the compensation counteracts this impairment and prevents the accident. This could be an explanation for the findings described above that detrimental effects of alcohol can be shown for different performance indicators in driving simulator studies, but not so clearly for crashes. In line with this reasoning, Christoforou et al. (2012) found that young drivers at BACs of 0.3 g/l reduced their speed under the influence of alcohol. They argued that at this level of intoxication drivers notice the influence of alcohol and try to counteract this in order to prevent an accident.

One interesting conclusion from this hypothesis is that negative alcohol effects including crashes should not be found in driving situations which seem risky for the driver, but in situations where the driver feels safe and does not expect that something might happen that requires immediate reactions. In risky situations, compensatory behavior is activated and may be sufficient to safely handle the situation. However, in seemingly safe and easy driving situations, the negative effects of alcohol hamper the abilities to react adequately if an unexpected, dangerous event happens and the full abilities of the driver are required. Thus, stronger alcohol effects which could also lead to more accidents should be found in 'easy' driving situations as compared to 'complex' situations, if these compensatory effects really play a role. This is in direct contrast to the results from the experimental studies described above where the alcohol effect was stronger for complex or controlled as compared to easy or automated tasks.

In order to test this hypothesis two driving simulator studies were done comparing easy and complex scenarios with drivers under the influence of alcohol with a placebo group in the first study. The second study used other scenarios in order to extend the validity of the findings and a sober control group to examine the effects of alcohol expectations. The overall aim was to better understand the psychological processes involved in accident causation under the influence of alcohol.

## 2. Study 1

The basic idea of this study was to test the hypothesis that intoxicated drivers try to compensate their impairment in situations which seem dangerous to them. In contrast, if the situation seems inconspicuous and easy to handle, compensation should not be shown leading to stronger negative alcohol effects. Moreover, these situations were supposed to be similar to typical situations in which accidents occur. To this aim, the results of an extended German in-depth accident study (Vollrath et al., 2006; Vollrath, 2010) were used to find these kind of situations and create respective scenarios in the driving simulator. These had already been used in other studies and have proven to lead to accidents in a similar manner as in real traffic (Werneke and Vollrath, 2012; Kazazi et al., 2015; Powelleit et al., 2015). Thus, a relatively high accident rate was to be expected in these situation even for sober drivers. This was done in contrast to most other studies cited above in order to focus on accident-prone situations. One of the scenarios involved an intersection where drivers were supposed to expect that something critical might happen. The other comprised of a straight section in town where there was no reason to expect any critical event.

In these scenarios, the reaction of intoxicated drivers in the driving simulator were compared to sober drivers in a placebo condition. It was expected that the intoxicated drivers would try to compensate for alcohol's effects in the complex, dangerous scenario, but not the seemingly easy one. Thus, more accident were supposed to happen under alcohol in the easy scenario, but not the complex one. The method of this study is described in the next section.

### 2.1. Method

#### 2.1.1. Sample

Only male students were included in the study. One reason for this was to avoid endangering women with possible pregnancies. Moreover, alcohol is much more frequent in male accident drivers as in women. For example, in Germany in 2014 only 13% of all intoxicated accident drivers were women (Statistisches Bundesamt, 2015). Overall, 48 subjects participated in the study. Most of them were students ranging in age from 20 to 29 years (mean 23.2, SD = 2.0). While this does not represent all age-groups typically found in alcohol-related accidents, accident risk is higher for younger drivers than for middle aged drivers (e.g, Krüger and Vollrath, 2004). Thus we decided for a homogenous sample with regard to age and to focus on these younger drivers. All subjects had a valid driver's license for at least two years. Half of the subjects received placebo, the other half alcohol.

All subjects were screened for possible alcohol problems using the LAST (Rumph et al., 1997). Only drivers which indicated no problems could participate. Moreover, subjects had to indicate their typical