# Predicting Drunk Driving Using a Variant of the Implicit Association Test

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## Author note

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**Abstract**

**Introduction.** Drunk driving is one of the primary causes of road traffic injuries and fatalities. A possible approach to reduce drunk driving rates is to identify which individuals are at risk of such behavior and establish targeted prevention. Simply asking individuals about drunk driving in real-world contexts would be problematic because of potential deception. The use of implicit measures such as the Implicit Association Test (IAT) could overcome this problem because they are less controllable than self-reports and thus less susceptible to deception. However, previous studies have shown poor predictive utility of implicit measures for drunk driving behavior. The current studies aimed to test the predictive utility of a variant of the IAT designed to assess beliefs about past driving under the influence (the P-DUI-IAT). **Method**. Study 1 ($N$ = 216) tested whether the P-DUI-IAT could predict self-reported prior drunk driving and future likelihood of drunk driving. We also examined incremental predictive validity of the P-DUI-IAT for these outcomes. A second study ($N$ = 159) examined whether results from Study 1 were reproducible. **Results.** In both studies, results showed that the P-DUI-IAT discriminated well between participants who had engaged in drunk driving and participants who had not. The P-DUI-IAT also showed independent and incremental predictive validity for past drunk driving and future likelihood of drunk driving. **Conclusions**. These studies provided initial evidence for the predictive utility of the P-DUI-IAT for drunk driving. **Practical Applications.** The P-DUI-IAT is a promising tool for identifying which individuals are at risk of drunk driving. The application of this measure could especially be valuable for identifying young novice drivers at risk for drunk driving-related accidents.

*Keywords:* implicit measures, drunk driving, prediction, past behavior

# Predicting Drunk Driving Using a Variant of the Implicit Association Test

## 1. Introduction

Road traffic injuries are the leading cause of death for children and young adults aged 5-29 years (World Health Organization [WHO], 2018). Despite growing efforts to reduce driving under the influence (DUI) of alcohol, it remains one of the primary causes of road traffic injuries and fatalities (WHO, 2018). An important approach to prevent DUI is implementing adequate training or other preventive measures. However, providing every individual with training would not be feasible (because it would be costly and time-consuming). Therefore, it is necessary to develop measures that identify individuals who are likely to drink and drive.

Traffic safety research has a long-standing tradition of using self-report measures of attitudes (such as questionnaires) to predict risky driving behaviors (e.g., Beck, 1981; Elliott, Armitage, & Baughan, 2003; McBride, Carter, & Phillips, 2020; Mohamed & Bromfield, 2017; Parker, Manstead, Stradling, Reason, & Baxter, 1992). Yet, evidence for the predictive utility of self-report measures of attitudes for drunk driving behavior is limited.

First, studies that examined this relationship have shown mixed results depending on several demographical factors. For instance, attitude questionnaires show predictive utility for DUI of alcohol and other risky driving behaviors in higher-income countries but not in lower-income countries (e.g., Ghasemzadeh, Babazadeh, Allahverdipour, Sadeghi-Bazargani, & Kouzekanani, 2017; Leandro, 2012; Lund & Rundmo, 2009; Siebert, Hellmann, Pant, Lin, & Trimpop, 2021; Şimşekoğlu, Nordfjærn, & Rundmo, 2012; Zhu, Zhang, Bao, & Sun, 2010). This trend is concerning considering that approximately 93% of traffic fatalities occur in those latter countries (WHO, 2020). Further, Rivis and colleagues (2011) showed that self-reported attitudes were predictive of DUI behavior in younger drivers but not in older drivers, while Moan and Rise (2011) showed the opposite pattern. Similarly, self-report measures of

attitudes have shown to predict drunk driving behavior in men, but not in women (e.g., Fernandes, Hatfield, & Job, 2010; Moan & Rise, 2011).

Second, while self-report attitude measures have shown predictive utility for *self-reported* drunk driving and other risky driving behaviors, studies that have examined their predictive utility for *actual* risky driving behavior have been scarce. Studies that did investigate this relation typically found no significant effects (e.g., Conner et al., 2007; Elliott, Armitage, & Baughan, 2007).

Such findings are not entirely surprising. At the end of the previous century, research in the attitudes domain revealed that self-report measures of attitudes were often not as good at predicting behavior as was initially expected (e.g., Wicker, 1969). To explain this finding, researchers resorted to dual-attitudes theories. According to this perspective, individuals do not only hold attitudes that are accessible through introspection (and thus can be measured through self-report) but also hold attitudes that are outside of conscious control, and subsequently, cannot deliberately be reported on (e.g., Greenwald & Banaji, 1995). Implicit measures were developed to tap into these "implicit attitudes" and, in turn, close the attitude-behavior gap.

One of the most frequently used implicit measures is the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998), a computer task in which participants are required to assign stimuli as fast as possible to one of four possible categories using one of two computer keys. The stimuli of a typical attitude IAT consist of two types of attitude objects (e.g., the words "drunk driving" and "sober driving") and two types of evaluation attributes (e.g., the words "good" and "bad"). In a first critical block, stimuli belonging to one of the two attitude objects and stimuli belonging to one of the two evaluation attributes share one response key (e.g., the E-key for categorizing "drunk driving" and "bad" stimuli), and the stimuli belonging to the other attitude object and evaluation attribute share the other response

key (e.g., the I-key for categorizing “sober driving” and “good” stimuli). In a second critical block, participants categorize the same stimuli again, but this time, with the reversed response key-assignment (e.g., the E-key for categorizing “sober driving” and “bad” stimuli and the I-key for categorizing “drunk driving” and “good” stimuli). IAT scores are obtained by computing the difference in performance between these two blocks. For this example, it is typically assumed that faster responding in the first critical block reflects a negative implicit attitude towards drunk driving.

However, after more than 25 years of research, it seems that implicit measures do not live up to the promise of closing the attitude-behavior gap. There has been little to no robust evidence showing that attitudes measured through implicit measures are qualitatively different from attitudes measured through self-report measures. Moreover, implicit measures of attitudes have shown poor predictive utility in several domains. Only few studies have shown that these implicit measures have added predictive utility above and beyond self-report measures of attitudes (see Meissner, Grigutsch, Koranyi, Müller, & Rothermund, 2019; Van Dessel et al., 2020, for detailed reviews).

Recently, however, implicit measures have been applied to the domain of traffic safety. Studies have shown that attitudes as measured through implicit measures relate to self-reports of different types of risky driving behaviors, such as seat-belt use (Ledesma, Tosi, Díaz-Lázaro, & Poó, 2018), helmet use (Ledesma, Tosi, Poó, Montes, & López, 2015), speeding (Hatfield, Fernandes, Faunce, & Job, 2008), and traffic violations (Rusu, Sârbescu, Moza, & Stancu, 2017). There is also initial evidence showing that such attitudes relate to objective risky driving behavior, such as observed helmet use (Ledesma et al., 2015) and speeding in a driving simulator (Hatfield et al., 2008). It is of note, however, that the relations reported in these studies were often weak to moderate (for a review see Tosi, Haworth, Díaz-Lázaro, Poó, & Ledesma, 2021). Notably, current evidence for the predictive utility of

implicit measures of attitudes for drunk driving behavior is also limited. A first study showed that an implicit measure of attitudes had (weak) value to predict drunk driving under the legal limit and no predictive value for drunk driving over the legal limit (Martinussen, Petranca, & Sømhovd, 2018). In a second study, Fernandes and colleagues (2006) observed a significant correlation between implicit measure scores and future intentions to drink and drive, but the direction of the relationship was contradictory to what was expected (i.e., more negative attitudes towards drunk driving were related to increased intentions to drink and drive).

To predict drunk driving, it could be more advantageous to target a construct that more consistently forecasts drunk driving. Importantly, prior drunk driving has not only repeatedly shown to be a strong predictor of self-reported intentions to drink and drive (e.g., Freeman et al., 2006; Freeman & Watson, 2006; Freeman et al., 2020; Watson-Brown, Truelove, Parker, & Davey, 2021) but also of actual drunk driving behavior (e.g., Ferrante, Rosman, & Marom, 2001; Hubicka, Laurell, & Bergman, 2008; Marowitz, 1996; Rauch et al., 2010; Robertson, Zhou, Tatch, & Walsh, 2019; Trimboli & Smith, 2009). Moreover, past drunk driving behavior has been shown to predict intentions to drink and drive above and beyond self-reported attitudes and other predictors (e.g., Potard, Kubiszewski, Camus, Courtois, & Gaymard, 2018).

Importantly, however, simply asking individuals about past drunk driving behavior could be problematic in certain contexts. It is well known that self-reports are susceptible to social desirability responding (i.e., responding in a way that is viewed favorably by others; af Wåhlberg, 2010; Lajunen, Corry, Summala, & Hartley, 1997). In research settings that guarantee anonymity of the participants, such deception might not be a big problem. This consideration is in line with the fact that self-reports of driving behavior (e.g., self-reports of prior reckless driving) do relate to actual driving behavior (e.g., in vehicle data recordings) within *research settings* (for a review see Kaye, Lewis, & Freeman, 2018). In *real-world*

*settings*, however, deception might be a more serious problem. More specifically, in such contexts, individuals would be highly motivated to be dishonest when being asked about prior drunk driving because of potential aversive consequences of admitting such behavior (e.g., mandatory training; Rogers, 1997).

The use of implicit measures in real-world contexts could overcome this problem. Although implicit measures can be controlled intentionally to some extent, they are less controllable than self-reports and thus less susceptible to attempts of deception (Agosta, Ghirardi, Zogmaister, Castiello, & Sartori, 2011). Importantly, these measures can also tap into beliefs about past behavior (e.g., Sartori, Agosta, Zogmaister, Ferrara, & Castiello, 2008). Hence, an IAT designed to capture beliefs about past drunk driving might be useful for capturing past drunk driving behavior that people do not want to report in real-life contexts. Such an IAT could therefore provide a unique way to help improve the prediction of future drunk driving.

We therefore developed a variant of the IAT that aims to assess past DUI behavior (the P-DUI-IAT). Stimuli of a typical IAT (such as an attitudes IAT) contain words such as, “drunk driving”, “sober driving”, “good”, and “bad”. Stimuli of the P-DUI-IAT, on the other hand, contain sentences rather than words. During the P-DUI-IAT, participants categorize statements regarding past drunk driving behavior or past non-drunk driving behavior (e.g., “drunk driving is something I have done” or “drunk driving is something I have not done”) together with statements that are logically true or false (e.g., “I’m doing a computer task” or “I’m playing football”). It can be expected that participants who have driven under the influence of alcohol before will respond faster to the combination of statements regarding past drunk driving and statements that are logically true (see Agosta & Sartori, 2013 for a review on similar IAT procedures).

The current studies' aim was to validate the P-DUI-IAT, a newly developed measure that can be of use for the detection of drunk driving in real-world contexts. We conducted this initial validation test by examining the relation between P-DUI-IAT scores and self-reports of drunk driving behavior which, as discussed above, have shown to be valid measures of actual driving behavior within anonymous research contexts. It is likely that P-DUI-IAT scores would show a similar relation to drunk driving in real-world contexts (in which self-reports of drunk driving are no longer valid indicators of actual drunk driving because of deception). More specifically, in Study 1, we examined the P-DUI-IAT's (a) ability to discriminate between participants who report to have driven drunk before (over the past month and the past year) and participants who report to not have driven drunk, (b) predictive utility for self-reported past drunk driving and future likelihood of drunk driving, and (c) ability to predict self-reported past and future likelihood of drunk driving above and beyond known risk factors of drunk driving: age, gender (e.g., Lipari, Hughes, & Bose, 2016), alcohol consumption (e.g., Stephens, Bishop, Liu, & Fitzharris, 2017), perceived behavioral control (e.g., Potard et al., 2018), and self-reported frequency of past DUIA behavior (for future likelihood of drunk driving behavior). The aim of Study 2 was to reproduce and extend the results from Study 1.

## 2. Study 1

All data files, study and analytic scripts of this study and Study 2 are publicly available on the Open Science Framework (see https://osf.io/wsmr3/)

### *2.1.Method*

#### *2.1.1. Participants*

We recruited English speaking participants via Prolific Academic, a platform for online participant recruitment. Participants received a small monetary reward (£2) after completing the study. We applied pre-screening filters so that only participants who had

previously indicated that they (a) had a valid driving license, (b) drove their car at least one a month, and (c) drank at least one to four units alcohol per week, could participate in the study.

A total of 312 participants started the study. At the beginning of the study, we asked additional inclusion questions to ensure that all participants met the inclusion criteria of driving their car often and drinking more than zero units of alcohol per week. The study was terminated for 37 participants who indicated to drink zero units of alcohol per week and/or drove less than 10 miles per week on average. The data of twelve participants who did not provide complete data (i.e., incomplete IAT and/or incomplete answers to questions/scales) were excluded from further analyses. Data of 43 participants who met the exclusion criteria of the IAT D4-scoring procedure were also excluded (i.e., response latencies less than 300 ms on 10% or more of the critical trials, error rates above 30% for all of the critical blocks, and/or error rates above 40% for any of the critical blocks). Additionally, the data of three participants were excluded because their response latencies were over 10.000 ms for the majority of P-DUIA-IAT trials. Finally, one participant indicated to have driven drunk in past month, but not in the past year. The data from this participant were excluded because we could not determine whether the participant did not pay attention when answering the questions or whether the questions were misinterpreted. Results did not change when excluding this participant's data.

The final sample size consisted of 216 participants. Sample characteristics are presented in Table 1. This sample included 132 participants who indicated to have not driven drunk and 84 participants who indicated to have driven drunk in the past year (14 of those participants indicated to also have driven drunk in the past month). These sample sizes provided 97% power to detect a medium effect size ($d$ = 0.50, alpha = .05, one-tailed) in the crucial between groups $t$-test (i.e., comparison of P-DUI-IAT scores between the offenders group and non-offenders group).

**Table 1**

*Sample Characteristics Study 1 Based on History of Drunk Driving*

| | Drunk driving past year ($n$ = 84) | No drunk driving ($n$ = 132) |
|---|---|---|
| Age | | |
| *M (SD)* | 38.04 (12.70) | 38.89 (11.82) |
| Min-Max | 18-73 | 20-69 |
| Range | 55 | 49 |
| Gender | | |
| % male (*n*) | 51.20% (43) | 43.20% (57) |
| % female (*n*) | 48.8% (41) | 56.80% (75) |
| Years of driving experience, *M* (*SD*) | 17.12 (11.83) | 17.77 (11.33) |
| Weekly mileage, *M* (*SD*) | 139.43 (119.34) | 154.55 (196.87) |
| Units of alcohol per week, *M* (*SD*) | 12.57 (11.43) | 8.87 (7.42) |
| Drunk driving frequency past year, *M* (*SD*) | 2.29 (0.48) | 0.00 (0.00) |
| Drunk driving frequency past month, *M* (*SD*) | 0.24 (0.69) | 0.00 (0.00) |

### *2.1.2. Materials*

*P-DUI-IAT.* The P-DUI-IAT was in line with standard procedures of the IAT (Nosek, Greenwald, & Banaji, 2007) and, more specifically, the autobiographical variant of the IAT (aIAT; Sartori et al., 2008), which uses sentences rather than words as stimuli. On each trial, a statement appeared in the middle of the screen. Participants were instructed to categorize those statements as fast as possible by pressing the "F" or "J" keys on the keyboard. Category labels were presented in the top left and right corners to aid categorization. If the response was correct, the stimulus disappeared, and the next stimulus was presented 400ms later. If the response was incorrect, a red cross replaced the stimulus for 200ms, and the next stimulus appeared 400ms after the red cross appeared. In the first block, participants practiced assigning statements regarding past DUI behavior (e.g., "I have driven while being drunk")

and past non-DUI behavior (e.g., “I have always driven while sober”) to the “I HAVE DRIVEN DRUNK BEFORE” and “I HAVE NEVER DRIVEN DRUNK” categories, respectively. In the second block, participants practiced assigning statements that were logically true (e.g., “I’m doing a computer task”) and statements that were logically false (e.g., “I’m climbing a mountain”) to the “TRUE” and “FALSE” categories, respectively. Both practice blocks consisted of 24 trials. Subsequently, participants completed 32 critical trials in which statements from all four categories were categorized. In these trials, statements regarding past DUI behavior and statements that were logically true shared the same response key (i.e., the left key), whereas statements regarding past non-DUI behavior and statements that were logically false shared the other response key (i.e., the right key). Then, participants practiced sorting statements regarding past DUI behavior and statements regarding past non-DUI behavior with the response key assignment reversed (i.e., the left key for statements regarding past non-DUI behavior and the right key for statements regarding past DUI behavior), for 24 trials. Finally, participants completed 32 trials in which statements from all four categories were categorized using the new response key assignment.

Scores for the P-DUI-IAT were calculated using the D4 scoring algorithm (Greenwald, Nosek, & Banaji, 2003). Reaction times on trials of the first critical block were subtracted from reaction times on trials of the second critical block, such that higher scores indicated faster responding in critical blocks in which statements regarding past DUI behavior and statements that were logically true shared the same response key (Spearman-Brown corrected split-half reliability = .70).

*Self-Report Measures of Past Drunk Driving.* To assess drunk driving behavior in the past year, we asked participants the following question: “In the past 12 months, as a road user, how often did you drive after drinking alcohol?”. Responses were provided on a Likert scale ranging from one (*never*) to five (*almost always*). To assess drunk driving in the past month,

we asked participants to indicate the number of times they had driven a car when they might have been over the legal limit for drinking and driving over the past 30 days.

*Self-Report Measures of Future Likelihood of Drunk Driving.* To assess future likelihood of drunk driving, we used both a single question and a subscale of the Behaviors and Attitudes Drinking and Driving Scale (BADDS; Jewell & Hupp, 2005). The single question asked "To what extent do you think you will be likely to drink and drive (again) in the future?". Responses were provided on a Likert scale ranging from one (*very unlikely*) to five (*very likely*). The Likelihood of Drinking and Driving Subscale (LDDS) of the BADDS (Cronbach's Alpha = .88) consists of 15 items and three parts. In the first part (i.e., the first five items), participants indicated how likely they would be to drive a *short* distance after having one, two, three, four, and six or more drinks. In the second and third part of the scale, participants indicated how likely they would be to drive a *medium* and *long* distance, respectively, after having those same numbers of drinks. All items were rated on a five-point Likert scale ranging from zero (*very unlikely*) to four (*very likely*). Total scores for this scale were calculated by summing the item scores.

*Measures of Risk Factors.* To measure alcohol consumption, we asked participants how many units of alcohol they drink on average per week. Perceived behavioral control (PBC) was measured using a subscale of a questionnaire developed by Marcil and colleagues (2001). Before answering the questions, participants were instructed to imagine that they drove their car to a party where they drank alcohol but were uncertain whether their blood alcohol level exceeded the legal limit when they had to return home. This subscale consisted of five questions (e.g., "For me, driving my car after drinking alcohol at the party is…"). Questions were answered on a bipolar scale ranging from -3 (e.g., *easy*) to +3 (e.g., *difficult*). Scores for each question were averaged to obtain the total score (Cronbach's Alpha = .88).

### *2.1.3. Procedure*

First, participants answered the inclusion questions regarding their car and alcohol use. Next, participants were asked to answer some demographical questions and completed the P-DUI-IAT. Before completing the scales and questions regarding DUI of alcohol, participants were reminded about the anonymous nature of the study (to reduce socially desirable responding). Participants first answered questions regarding their past drunk driving behavior. After that, they completed the PBC scale. Finally, participants completed the LDDS and answered the single question regarding future likelihood of drunk driving.

#### *2.1.4. Data-Analysis*

We used independent two samples *t*-tests to examine whether the P-DUI-IAT could discriminate between participants who had driven drunk (over the past year and the past month) and participants who had not driven drunk. To examine how well the P-DUI-IAT discriminates between these groups, we conducted receiver-operating-characteristic (ROC) analyses and we tested different cut-off points of the P-DUI-IAT to probe maximum sensitivity (true positive rate) and specificity (true negative rate). To examine the ability of the P-DUI-IAT to independently predict past drunk driving, we performed logistic regression analyses. Linear regression analyses were used to examine the ability of the P-DUI-IAT to independently predict future likelihood of drunk driving. Finally, to examine the ability of the P-DUI-IAT to incrementally predict past drunk driving and future likelihood of drunk driving, we used hierarchical regression analyses[1]. For these analyses, significant risk factors were added in the first step and P-DUI-IAT scores were entered in the second step.

### *2.2.Results*

[1] For the past drunk driving outcomes, logistic regression analyses were used (and thus the past DUI variables were coded as 0 or 1) because we were mainly interested in testing whether P-DUI-IAT scores were able to predict group status (DUI-offender or non-offender) rather than the severity (i.e., frequency) of DUI behavior. Linear regression analyses were used for the future likelihood outcomes because these measures were rated on a Likert scale for which the category labels ranged from very unlikely to very likely.

### *2.2.1. Ability of the P-DUI-IAT to Discriminate Between the Past Drunk Driving and No Past Drunk Driving Group*

Analyses revealed that participants who had driven drunk in the past month exhibited significantly larger P-DUI-IAT scores ($M$ = 0.31, $SD$ = 0.44) than participants who had not driven drunk ($M$ = -0.07, $SD$ = 0.42), $t(15.65) = 3.13$, $d$ = 0.90, $p$ = .003. We did not observe significant differences in P-DUI-IAT scores between participants who had driven drunk in the past year ($M$ = -0.02, $SD$ = 0.40) and participants who had not driven drunk ($M$ = -0.07, $SD$ = 0.42), $t(183.05) = 0.84$, $d$ = 0.12, $p$ = .20.

The Area Under the Curve (AUC) or the overall ability of the P-DUI-IAT to correctly classify participants was .73 (95% CI = 0.60-0.87) for past month drunk driving, whereas the AUC for past year drink driving was around chance level (.48, 95% CI = 0.40-0.56). Using zero as the cut-off score for the P-DUI-IAT, which is often considered theoretically relevant (e.g., Cvencek et al., 2020), produced 57% specificity and 71% sensitivity for detecting past month DUI. The threshold to maximize sensitivity and retain fair specificity (-0.08 IAT score) produced 86% sensitivity and 48% specificity. The threshold to maximize specificity and retain fair sensitivity (-0.41 IAT score) produced 90% specificity and 43% sensitivity. Using these same cut-off scores for the P-DUI-IAT produced 15 to 49% sensitivity and 48% to 90% specificity to detect past year drunk driving.

### *2.2.2. Ability of the P-DUI-IAT to Independently Predict Drunk Driving*

Higher P-DUI-IAT scores were significantly associated with past month drunk driving, OR = 6.90, 95% CI = [1.99, 26.55], $p$ = .003, but not with past year drunk driving, OR = 1.33, 95% CI = [0.68, 2.60], $p$ = .40. P-DUI-IAT scores significantly predicted future likelihood to drink and drive as measured with the LDDS, $B$ = 4.16, $t(214) = 3.02$, $p$ = .003, but did not predict responses to the single future likelihood question, $B$ = 0.19, $t(214) = 1.12$, $p$ = .26.

### *2.2.3. Ability of the P-DUI-IAT to Incrementally Predict Drunk Driving*

Significant risk factors of drunk driving for each outcome (see Table 2) were statistically controlled for in subsequent analyses. Hierarchical logistic regression analyses showed that P-DUI-IAT scores predicted past month drunk driving (see Table 3) above and beyond risk factors of drunk driving. The P-DUI-IAT did not show incremental validity for the prediction of past year drunk driving (see Table 4). Hierarchical linear regression showed that P-DUI-IAT scores significantly predicted LDDS scores after controlling for risk factors of drunk driving, $F(1, 210) = 5.67$, $p = .02$, $\Delta R^2 = .02$, but did not significantly predict responses to the single future likelihood question after controlling for risk factors of drunk driving, $F(1, 209) = 0.41$, $p = .52$, $\Delta R^2 = .00$.

**Table 2**

*Risk Factors for Drunk Driving (Study 1)*

| Variable | Past month DUI OR (95% CI) | Past year DUI OR (95% CI) | LDDS *B* | Single FL question *B* |
|---|---|---|---|---|
| Gender (male) | 3.29 (1.04, 12.48) | 1.38 (0.80, 2.40) | 2.63* | 0.43** |
| Age | 1.00 (0.95, 1.04) | 0.99 (0.97, 1.02) | -0.08 | 0.00 |
| Units of alcohol | 1.06* (1.00, 1.13) | 1.04** (1.01, 1.08) | 0.12 | 0.02** |
| PBC | 2.40*** (1.62, 3.80) | 1.79*** (1.41, 2.34) | 3.18*** | 0.36*** |
| Past year DUI | - | - | 6.43*** | 0.94*** |
| Past month DUI | - | - | 4.86*** | 0.83*** |

*Note.* PBC = perceived behavioral control; DUI = driving under the influence; LDDS = Likelihood of Drinking and Driving Scale; FL = future likelihood; OR = odds ratio; CI = confidence interval.

* $p < .05$. ** $p < .01$. *** $p < .001$.

**Table 3**

*Hierarchical Logistic Regression Predicting Past Month Drunk driving (Study 1)*

| Variable | *B* | *SE* | Wald | OR (95% CI) | $\chi^2$ | $R^2$ |
|---|---|---|---|---|---|---|
| Step 1 | | | | | $\chi^2(2) = 23.56$*** | 0.32 |
| Units of alcohol | 0.06 | 0.04 | 3.00 | 1.06 (0.99, 1.34) | | |
| PBC | 0.84 | 0.21 | 16.7 | 2.32*** (1.76, 4.77) | | |
| Step 2 | | | | | $\chi^2(1) = 5.73$* | 0.39 |
| P-DUI-IAT scores | 1.84 | 0.77 | 5.80 | 6.32* (1.41, 30.43) | | |

*Note.* PBC = perceived behavioral control; P-DUI-IAT = past driving under the influence implicit association test; OR = odds ratio; CI = confidence interval.

* $p < .05$. *** $p < .001$.

**Table 4**

*Hierarchical Logistic Regression Predicting Past Year Drunk driving (Study 1)*

| Variable | *B* | *SE* | Wald | OR (95% CI) | $\chi^2$ | $R^2$ |
|---|---|---|---|---|---|---|
| Step 1 | | | | | $\chi^2(2) = 32.24$*** | 0.19 |
| Units of alcohol | 0.04 | 0.02 | 6.50 | 1.04* (1.01, 1.08) | | |
| PBC | 0.58 | 0.13 | 19.90 | 1.79*** (1.40, 2.34) | | |
| Step 2 | | | | | $\chi^2(1) = 0.04$ | 0.19 |
| P-DUI-IAT scores | 0.08 | 0.15 | 0.04 | 1.08 (0.52, 2.23) | | |

*Note.* PBC = perceived behavioral control; P-DUI-IAT = past driving under the influence implicit association test; OR = odds ratio; CI = confidence interval.

* $p < .05$. *** $p < .001$.

### *2.3. Discussion*

Results of Study 1 provide initial evidence for predictive value of the P-DUI-IAT for drunk driving behavior. First, the P-DUIA-IAT discriminated well between participants who reported to have driven drunk over the past month and participants who reported to have not driven drunk. Second, higher P-DUI-IAT scores were strongly associated with self-reports of past month drunk driving and future likelihood of drunk driving (as measures with the

LDDS), and improved prediction of these outcomes above and beyond known risk factors of drunk driving.

Notably, results did not show predictive validity of the P-DUI-IAT for self-reports of drunk driving over the past year. This finding might seem to contradict findings for drunk driving over the past month. One possible explanation is that the P-DUI-IAT might only reflect more recent behavior. Alternatively, this observation might relate to differences in the of the questions regarding past drunk driving. For the past year question, participants were asked to indicate how often they *had driven after they drank alcohol*. For the past month question, however, participants were asked how many times they *had driven a car when they might have been over the legal limit for drinking and driving*. The P-DUI-IAT may only be predictive of drunk driving when one is over the legal limit for drunk driving but not when under the legal limit (possibly because the IAT category labels relate to drunk driving rather than driving after drinking alcohol).

## 3. Study 2

### *3.1.Method*

#### *3.1.1. Participants*

As in Study 1, participants who (a) were English speaking, (b) had a valid driving license, (c) drove their car at least once a month, and (d) drank at least one to four units alcohol per week, were recruited via Prolific Academic. We first ran a short prescreening study to allow recruiting of more participants who had driven drunk (i.e., by asking prospective participants how many times they had driven drunk in the past). We invited 220 participants for the main study (i.e., 110 participants who had driven drunk and 110 participants who had not driven drunk). Participants received a small monetary reward after completing the prescreening (£0.10) and main study (£2).

A total of 198 of the invited participants started the main study. Data of participants who provided incomplete data ($n$ = 14) or met the exclusion criteria of the IAT D4-scoring procedure ($n$ = 23) were excluded from further analyses. Additionally, the data of two participants were excluded because they indicated to have driven drunk in the past month, but not in the past year. The final sample size consisted of 159 participants. This sample included 99 participants who had not driven drunk and 60 participant who had driven drunk over the past year (32 of those participants indicated to also have driven drunk over the past month). These sample sizes provided 92% power to detect a medium effect size ($d$ = 0.50, alpha = .05, one-tailed) in the crucial between groups $t$-test. Sample characteristics are presented in Table 5.

**Table 5**

*Sample Characteristics Study 2 Based on History of Drunk Driving*

| | Drunk driving past year ($n$ = 60) | No drunk driving ($n$ = 99) |
|---|---|---|
| Age | | |
| *M (SD)* | 38.17 (13.91) | 43.38 (12.60) |
| Min-Max | 19-67 | 18-69 |
| Range | 48 | 51 |
| Gender | | |
| % male ($n$) | 50% (30) | 31.30% (31) |
| % female ($n$) | 50% (30) | 68.70% (68) |
| Years of driving experience, *M* (*SD*) | 17 (13.04) | 21.67 (12.15) |
| Weekly mileage, *M* (*SD*) | 124.17 (138.46) | 244.58 (837.78) |
| Units of alcohol per week, *M* (*SD*) | 13.05 (17.26) | 11.16 (15.99) |
| Drunk driving frequency past year, *M* (*SD*) | 6.05 (19.36) | 0.00 (0.00) |
| Drunk driving frequency past month, *M* (*SD*) | 0.90 (1.66) | 0.00 (0.00) |

### *3.1.2. Materials and Procedure*

The materials and procedure were identical to Study 1 with two exceptions. First, to increase reliability of the P-DUI-IAT, we provided 48 instead of 32 trials for the critical blocks (Spearman-Brown corrected split-half reliability = .75). Second, to assess drunk driving in the past year, we used the same phrasing and response scale of the question to assess drunk driving in the past month (i.e., “In the past 12 months, how many times did you drive a car, when you may have been over the legal limit for drinking and driving?”).

### *3.1.3. Data-Analysis*

We used the same analyses as in Study 1. We also tested whether the Study 1 cut-off scores for the P-DUI-IAT to maximize sensitivity or specificity remained meaningful in the current sample.

## *3.2.Results*

### *3.2.1. Ability of the P-DUI-IAT to Discriminate Between the Past Drunk Driving and No Past Drunk Driving Group*

Analyses revealed significant differences in P-DUI-IAT scores between participants who had not driven drunk ($M$ = -0.16, $SD$ = 0.36) on the one hand, and participants who had driven drunk in the past month ($M$ = 0.20, $SD$ = 0.36), $t(53.05) = 4.92$, $d$ = 0.99, $p < .001$, and participants who had driven drunk in the past year ($M$ = 0.16, $SD$ = 0.38), $t(119.38) = 5.12$, $d$ = 0.85, $p < .001$, on the other hand.

The AUCs were .77 (95% CI = 0.68, 0.86) and .73 (95% CI = 0.64, 0.81) for past month and past year drunk driving, respectively. Using zero as the cut-off score for the P-DUI-IAT produced 69% specificity and 67 to 69% sensitivity. Using -0.08 as the cut-off score produced 73-78% sensitivity and 63% specificity, whereas using 0.41 as the cut-off produced 91 to 92% specificity and 22% sensitivity.

### *3.2.2. Ability of the P-DUI-IAT to Independently Predict Drunk Driving*

Analyses revealed that higher P-DUI-IAT scores were significantly associated with past month drunk driving, OR = 14.31, 95% CI = [4.38, 54.55], $p < .001$, and with past year drunk driving, OR = 9.47, 95% CI = [3.72, 26.62], $p < .001$. Moreover, P-DUI-IAT scores significantly predicted future likelihood to drink and drive as measured with the LDDS, $B$ = 11.42, $t(157) = 5.59$, $p < .001$, and as measured with the single future likelihood question, $B$ = 1.14, $t(157) = 5.59$, $p < .001$.

### *3.2.3. Ability of the P-DUI-IAT to Incrementally Predict Drunk Driving*

Significant risk factors of drunk driving for each outcome (see Table 6) were statistically controlled for in subsequent analyses. Hierarchical logistic regression analyses showed that P-DUI-IAT scores predicted past month drunk driving (see Table 7) and past year drunk driving (see Table 8) above and beyond risk factors of drunk driving. Hierarchical linear regression showed that, after controlling for risk factors of drunk driving, P-DUI-IAT scores predicted LDDS scores, $F(1, 153) = 10.38$, $p = .002$, $\Delta R^2 = .03$, and responses to the single future likelihood question, $F(1, 153) = 9.84$, $p = .002$, $\Delta R^2 = .03$.

**Table 6**

*Risk Factors for Drunk Driving (Study 2)*

| Variable | Past month DUI OR (95% CI) | Past year DUI OR (95% CI) | LDDS *B* | Single FL question *B* |
|---|---|---|---|---|
| Gender (male) | 2.49* (1.10, 5.67) | 2.19* (1.14, 4.27) | 3.76* | 0.47** |
| Age | 0.96* (0.93, 0.99) | 0.97* (0.94, 0.99) | -0.12 | -0.01 |
| Units of alcohol | 1.04 (0.99, 1.04) | 1.06 (0.99, 1.02) | 0.08 | 0.01 |
| PBC | 2.18*** (1.63, 3.03) | 2.14*** (1.67, 2.82) | 4.15*** | 0.43*** |
| Past year DUI | - | - | 0.19* | 0.02** |
| Past month DUI | - | - | 3.17*** | 0.35*** |

*Note.* PBC = perceived behavioral control; DUI = driving under the influence; LDDS = Likelihood of Drinking and Driving Scale; FL = future likelihood; OR = odds ratio; CI = confidence interval.

* $p < .05$. ** $p < .01$. *** $p < .001$.

**Table 7**

*Hierarchical Logistic Regression Predicting Past Month Drunk driving (Study 2)*

| Variable | *B* | *SE* | Wald | OR (95% CI) | $\chi^2$ | $R^2$ |
|---|---|---|---|---|---|---|
| Step 1 | | | | | $\chi^2(3) = 37.34$*** | 0.37 |
| Gender (male) | 0.79 | 0.49 | 2.60 | 2.21 (0.84, 5.88) | | |
| Age | -0.04 | 0.02 | 3.40 | 0.96 (0.93, 1.00) | | |
| PBC | 0.74 | 0.16 | 21.40 | 2.10*** (1.56, 2.95) | | |
| Step 2 | | | | | $\chi^2(1) = 9.22$** | 0.45 |
| P-DUI-IAT scores | 2.15 | 0.74 | 8.50 | 8.59** (2.11, 39.25) | | |

*Note.* PBC = perceived behavioral control; P-DUI-IAT = past driving under the influence implicit association test; OR = odds ratio; CI = confidence interval.

** $p < .01$. *** $p < .001$.

**Table 8**

*Hierarchical Logistic Regression Predicting Past Year Drunk driving (Study 2)*

| Variable | *B* | *SE* | Wald | OR (95% CI) | $\chi^2$ | $R^2$ |
|---|---|---|---|---|---|---|
| Step 1 | | | | | $\chi^2(3) = 52.89$*** | 0.39 |
| Gender (male) | 0.61 | 0.41 | 2.20 | 1.83 (0.82, 4.11) | | |
| Age | -0.04 | 0.02 | 6.20 | 0.96* (0.93, 0.99) | | |
| PBC | 0.74 | 0.14 | 29.10 | 2.11*** (1.63, 2.81) | | |
| Step 2 | | | | | $\chi^2(1) = 7.95$** | 0.43 |
| P-DUI-IAT scores | 1.60 | 0.58 | 7.50 | 4.95** (1.62, 16.19) | | |

*Note.* PBC = perceived behavioral control; P-DUI-IAT = past driving under the influence implicit association test; OR = odds ratio; CI = confidence interval.

* $p < .05$. ** $p < .01$. *** $p < .001$.

### *3.3.Discussion*

Results of Study 2 were in line with those of Study 1. First, P-DUI-IAT scores were strongly related to (a) self-reports of drunk driving over the past month and (b) future likelihood of drunk driving as measured with the LDDS. Second, the P-DUI-IAT showed incremental validity for these outcomes. Results of study 2 extended those of Study 1 by showing strong predictive value of the P-DUI-IAT for drunk driving in the past year. Participants who had driven drunk in the past year exhibited significantly higher P-DUI-IAT scores than participants who had not driven drunk. P-DUI-IAT scores also significantly predicted drunk driving over the past year and improved prediction of this outcome above and beyond known risk factors of drunk driving. Finally, results of Study 2 showed that P-DUI-IAT scores (incrementally) predicted future likelihood of drunk driving as measured with the single future likelihood question.

## 4. General Discussion

In this paper, we introduce the P-DUI-IAT, a new implicit measure designed to predict drunk driving behavior. Two studies found initial evidence for good predictive utility of the P-DUI-IAT. First, both studies showed that the P-DUI-IAT discriminated well between participants who reported to have driven drunk in the past month and participants who reported to have not driven drunk, and predicted this outcome above and beyond known risk factors of drunk driving. Secondly, the P-DUI-IAT showed strong predictive value for self-reported future likelihood of drunk driving and added predictive value above and beyond known risk factors. As opposed to the results of Study 1, results of Study 2 revealed that the P-DUI-IAT also showed strong predictive utility for self-reported *past year* drunk driving. Given the different phrasing that was used for the past year drunk driving question in both

studies, this pattern might indicate that the P-DUI-IAT is predictive of driving when over the legal limit for drinking and driving, but not when under the legal limit, which is important for practical reasons (i.e., prediction of DUI, rather than driving after drinking alcohol).

### *4.1.Practical Implications*

These findings can have important practical implications. Given that the P-DUI-IAT is less susceptible to social desirability responding than self-report measures, this measure can have practical utility in real-world contexts. In several European countries for instance, individuals have to return to driving school six to nine months after obtaining their driving license for a day of education on road safety behavior. The P-DUI-IAT could be administered in this context to identify individuals who are at risk of drinking and driving. Subsequently, those individuals could be provided with (extra) training or other preventive measures before negative consequences occur (e.g., fatal accidents). Targeting young novice drivers who are at risk of DUI recidivism would be a powerful strategy to reduce DUI-related accidents. It is well documented that (a) this population group is overrepresented in road crashes (e.g., Goldenbeld, Nuyttens, & Temmerman, 2018; WHO, 2018), and (b) this group is at much higher risk of being involved in a crash when being under the influence of alcohol compared to other population groups (e.g., Boets, Teuchies, Desmet, & Van Belle, 2020; WHO, 2015).

Another possibility is to use the P-DUI-IAT for diagnostic purposes (e.g., revoking or suspending one's driving license). Notably, however, the utility of implicit measures outside of academics has rarely been examined and the P-DUI-IAT's ability to correctly classify participants was not perfect (i.e., AUC, sensitivity, and specificity). Therefore, it would be premature to use the current version of the P-DUI-IAT for diagnostic purposes (e.g., Ledesma et al., 2015). However, the P-DUI-IAT could be used for diagnostic purposes in combination with other predictors of DUI once further (applied) research has been conducted and

classification values (such as sensitivity) of the P-DUI-IAT have been improved (for example, by altering different aspects of the P-DUI-IAT).

### *4.2.Limitations and Future Directions*

The current studies are not without their limitations. First, we measured drunk driving through self-report measures, which could have caused social desirability bias. Importantly, however, individuals are more likely to give honest answers in an anonymous research context than in a real-life context when negative consequences are at stake. The current studies were conducted online, which might have further facilitated truthful responding as previous studies have shown that individuals disclose more sensitive information online than in person (e.g., Booth-Kewley, Larson, & Miyoshi, 2007; Dayan, Paine, & Johnson, 2007; Joinson, 2001; Kays, Gathercoal, & Buhrow, 2012). To this end, we ensured participants that all of the data would be processed anonymously. This was done at the beginning of the study and before administering the self-report questions regarding drunk driving. Nevertheless, future studies should further validate the predictive utility of the P-DUI-IAT by examining its relation with more objective measures of drunk driving (such as driving records). Similarly, the current studies examined the predictive utility of the P-DUI-IAT for self-reported future likelihood of drunk driving. Using a longitudinal design could provide more definitive conclusions regarding the utility of the P-DUI-IAT for predicting future drunk driving.

Second, some of the questions within the current studies were formulated ambiguously. For instance, when asking participants how many units of alcohol they drink on average per week, we did not specify what a “unit” entails. Relatedly, participants were asked to indicate whether they had driven their car when they *may* have been over the legal limit for drinking and driving. It is possible that some participants were not aware of the exact legal limit for drinking and driving within their country or are unable to estimate when their Blood Alcohol Concentration (BAC) exceeds the legal limit for drinking and driving (e.g., Keatley,

O'Donnell, & Joyce, 2020*).* Future studies should explain the definition of a unit of alcohol to participants, as well as what being over the legal limits for drinking and driving entails and/or use additional questions to assess past drunk driving, such as the Drinking and Driving Behaviors items of the BADDS (which ask respondents how many times they have driven in the past month, one hour after having one or two drinks and three or more drinks; Jewell & Hupp, 2005).

Third, the current studies did not test whether the P-DUI-IAT is susceptible to faking, which might be important for practical reasons. Some previous studies that have examined fakability in implicit measure procedures found that individuals were sometimes able to strategically alter their test outcomes (e.g., Verschuere, Prati, & De Houwer, 2009). Importantly, however, in these studies, participants received detailed instructions on how to fake the implicit measure, which is not typically the case in real-world contexts. Also, several techniques were developed to detect or prevent faking during implicit measures (e.g., Agosta et al., 2011; Suchotzki, Verschuere, & Gamer, 2021). Nonetheless, future studies could examine whether individuals that have driven drunk (e.g., individuals who have been convicted of DUI) can fake the P-DUI-IAT .

Fourth, as discussed above, the P-DUI-IAT could be a useful tool for detecting DUI in young novice drivers. The current study samples, however, mainly consisted of older, experienced drivers (see Table 1 and Table 5). It is of note that explorative analyses including only participants between the age of 18 and 30 revealed results that were in line with those from Study 2 (see supplementary materials at https://osf.io/wsmr3/). Of course, these results should be interpreted with caution given the small sample size ($N$ = 44). Relatedly, all participants from the current study samples had a British nationality. Before the P-DUI-IAT can be used as a risk assessment tool, for example, in young novice drivers and in different

(e.g., lower-income) countries, future studies should test the generalizability of the current results.

Finally, the current studies were limited to the prediction of drunk driving and did not examine predictive utility of the P-DUI-IAT for other forms of DUI (e.g., driving under the influence of drugs or medication). Future studies could test whether the P-DUI-IAT is sensitive to other forms of DUI behavior or test alternative versions of the P-DUI-IAT that incorporate statements about (non) past driving under the influence of drugs or medication.

### *4.3.Conclusions*

The current studies showed initial evidence for the predictive utility of the P-DUI-IAT for drunk driving. The P-DUI-IAT could be a promising tool for risk assessment of drunk driving in real-world contexts, allowing for more targeted prevention to reduce DUI-related accidents. Future research should further examine the practical utility of this newly developed measure.

## References

af Wåhlberg, A. E. (2010). Social desirability effects in driver behavior inventories. *Journal of Safety Research*, *41*(2), 99-106. https://doi.org/10.1016/j.jsr.2010.02.005

Agosta, S., & Sartori, G. (2013). The autobiographical IAT: a review. *Frontiers in Psychology*, *4*, 519. https://doi.org/10.3389/fpsyg.2013.00519

Agosta, S., Ghirardi, V., Zogmaister, C., Castiello, U., & Sartori, G. (2011). Detecting fakers of the autobiographical IAT. *Applied Cognitive Psychology*, *25*(2), 299-306. https://doi.org/10.1002/acp.1691

Beck, K. H. (1981). Driving while under the influence of alcohol: Relationship to attitudes and beliefs in a college population. *The American Journal of Drug and Alcohol Abuse*, *8*(3), 377-388. https://doi.org/10.3109/00952998109009561

Boets, S., Teuchies, M., Desmet, C., & Van Belle, G. (2020). *Impact of alcohol on driving inyoung/novice drivers – A driving simulator study on the impact of a blood alcohol concentration of 0,2 g/L and 0,5 g/L on driving behaviour* (Research report N° 2018-R-10-SEN). Retrieved from Vias institute – Knowledge Centre Road Safety, Brussels, Belgium website: https://www.vias.be/en/research/notre-publications/

Booth-Kewley, S., Larson, G. E., & Miyoshi, D. K. (2007). Social desirability effects on computerized and paper-and-pencil questionnaires. *Computers in human behavior*, *23*(1), 463-477. https://doi.org/10.1016/j.chb.2004.10.020

Conner, M., Lawton, R., Parker, D., Chorlton, K., Manstead, A. S., & Stradling, S. (2007). Application of the theory of planned behaviour to the prediction of objectively assessed breaking of posted speed limits. *British journal of psychology*, *98*, 429-453. https://doi.org/10.1348/000712606X133597

Cvencek, D., Meltzoff, A. N., Maddox, C. D., Nosek, B. A., Rudman, L. A., Devos, T. Dunham, Y., Baron, A.S., Steffens, M.C., Lane, K., Horcajo, J., Ashburn-Nardo, L., Quinby, A., Srivastava, S. B., Schmidt, K., Aidman, E., Tang, E., Farnham, S., Mellott, D. S., Banaji, M. R., & Greenwald, A. G. (2020). Meta-analytic use of balanced identity theory to validate the implicit association test. *Personality and Social Psychology Bulletin*, *47*(2), 185-200. https://doi.org/10.1177/0146167220916631

Dayan, Y., Paine, C. S., & Johnson, A. J. (2007). Responding to sensitive questions in surveys: A comparison of results from Online panels, face to face, and self-completion interviews. *World Association for Public Opinion Research, Berlin*. Retrieved from http://www.ipsos-mori.com

Elliott, M. A., Armitage, C. J., & Baughan, C. J. (2003). Drivers' compliance with speed limits: An application of the theory of planned behavior. *Journal of Applied Psychology*, *88*(5), 964. https://doi.org/10.1037/0021-9010.88.5.964

Elliott, M. A., Armitage, C. J., & Baughan, C. J. (2007). Using the theory of planned behaviour to predict observed driving behaviour. *British Journal of Social Psychology, 46(1)*, 69-90. https://doi.org/10.1348/014466605X90801

Fernandes, R., Hatfield, J., & Job, R. S. (2010). A systematic investigation of the differential predictors for speeding, drink-driving, driving while fatigued, and not wearing a seat belt, among young drivers. *Transportation Research Part F: Traffic Psychology and Behaviour*, *13*(3), 179-196. https://doi.org/10.1016/j.trf.2010.04.007

Fernandes, R., Hatfield, J., Job, R. F. S. (2006). *Examination of different predictors of different risky driving behaviours in young NSW drivers. Final Report for the Motor Accidents Authority of NSW*. Retrieved from The University of New South Wales,

NSW Injury Risk Management Research Centre website: http://www.irmrc.unsw.edu.au/

Ferrante, A. M., Rosman, D. L., & Marom, Y. (2001). Novice drink drivers, recidivism and crash involvement. *Accident Analysis & Prevention, 33*(2), 221-227. https://doi.org/10.1016/S0001-4575(00)00035-X

Freeman, J., & Watson, B. (2006). An application of Stafford and Warr's reconceptualisation of deterrence to a group of recidivist drink drivers. *Accident Analysis & Prevention, 38*(3), 462-471. https://doi.org/10.1016/j.aap.2005.11.001

Freeman, J., Liossis, P., Schonfeld, C., Sheehan, M., Siskind, V., & Watson, B. (2006). The self-reported impact of legal and non-legal sanctions on a group of recidivist drink drivers. *Transportation Research Part F: Traffic Psychology and Behaviour*, *9*(1), 53-64. https://doi.org/10.1016/j.trf.2005.08.005

Freeman, J., Parkes, A., Lewis, N., Davey, J. D., Armstrong, K. A., & Truelove, V. (2020). Past behaviours and future intentions: an examination of perceptual deterrence and alcohol consumption upon a range of drink driving events. *Accident Analysis & Prevention*, *137*, 105428. https://doi.org/10.1016/j.aap.2019.105428

Ghasemzadeh, S., Babazadeh, T., Allahverdipour, H., Sadeghi-Bazargani, H., & Kouzekanani, K. (2017). Cognitive-behavioral determinants of using helmet by motorcyclists in a rural community. *Journal of Transport & Health*, *6*, 548-554. https://doi.org/10.1016/j.jth.2017.04.007

Goldenbeld, C., Nuyttens, N., & Temmerman, T. (2018). *Thematic File Road Safety N° 12 – Young people (15-24)* (Research report N° 2017-T-04-SEN). Retrieved from Vias institute – Knowledge Centre Road Safety, Brussels, Belgium website: https://www.vias.be/en/research/notre-publications/

Greenwald, A. G., & Banaji, M. R. (1995). Implicit social cognition: attitudes, self-esteem, and stereotypes. *Psychological Review*, *102*(1), 4-27. https://doi.org/10.1037/0033-295x.102.1.4.

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. (1998). Measuring individual differences in implicit cognition: the implicit association test. *Journal of personality and social psychology*, *74*(6), 1464-1480. https://doi.org/10.1037//0022-3514.74.6.1464.

Greenwald, A. G., Nosek, B. A., & Banaji, M. R. (2003). Understanding and using the implicit association test: I. An improved scoring algorithm. *Journal of Personality and Social Psychology*, *85*(2), 197-216. https://doi.org/10.1037/0022-3514.85.2.197

Hatfield, J., Fernandes, R., Faunce, G., & Job, R. S. (2008). An implicit non-self-report measure of attitudes to speeding: Development and validation. *Accident Analysis & Prevention*, *40*(2), 616-627. https://doi.org/10.1016/j.aap.2007.08.020

Hubicka, B., Laurell, H., & Bergman, H. (2008). Criminal and alcohol problems among Swedish drunk drivers - Predictors of DUI relapse. *International Journal of Law and Psychiatry*, *31*(6), 471-478. https://doi.org/10.1016/j.ijlp.2008.09.003

Jewell, J., & Hupp, S. D. (2005). Examining the effects of fatal vision goggles on changing attitudes and behaviors related to drinking and driving. *Journal of Primary Prevention*, *26*(6), 553-565. https://doi.org/10.1007-s10935-005-0013-9

Joinson, A. N. (2001). Self-disclosure in computer-mediated communication: The role of self-awareness and visual anonymity. *European journal of social psychology*, *31*(2), 177-192. https://doi.org/10.1002/ejsp.36

Kaye, S. A., Lewis, I., & Freeman, J. (2018). Comparison of self-report and objective measures of driving behavior and road safety: A systematic review. *Journal of Safety Research*, *65*, 141-151. https://doi.org/10.1016/j.jsr.2018.02.012

Kays, K., Gathercoal, K., & Buhrow, W. (2012). Does survey format influence self-disclosure on sensitive question items?. *Computers in Human Behavior*, *28*(1), 251-256. https://doi.org/10.1016/j.chb.2011.09.007

Keatley, D. A., O'Donnell, C., & Joyce, T. (2020). Perceptions of drink driving legal limits in England: A qualitative investigation. *Psychology, Crime & Law*, *26*(8), 733-744. https://doi.org/10.1080/1068316X.2020.1733569

Lajunen, T., Corry, A., Summala, H., & Hartley, L. (1997). Impression management and self-deception in traffic behaviour inventories. *Personality and Individual Differences*, *22*(3), 341-353. https://doi.org/10.1016/S0191-8869(96)00221-8

Leandro, M. (2012). Young drivers and speed selection: A model guided by the Theory of Planned Behavior. *Transportation Research Part F: Traffic Psychology and Behaviour*, *15*(3), 219-232. https://doi.org/10.1016/j.trf.2011.12.011

Ledesma, R. D., Tosi, J. D., Díaz-Lázaro, C. M., & Poó, F. M. (2018). Predicting road safety behavior with implicit attitudes and the Theory of Planned Behavior. *Journal of Safety Research*, *66*, 187-194. https://doi.org/10.1016/j.jsr.2018.07.006

Ledesma, R. D., Tosi, J., Poó, F. M., Montes, S. A., & López, S. S. (2015). Implicit attitudes and road safety behaviors. The helmet-use case. *Accident Analysis & Prevention*, *79*, 190-197. https://doi.org/10.1016/j.aap.2015.03.030

Lipari, R. N., Hughes, A., & Bose, J. (2016). *Driving under the influence of alcohol and illicit drugs. The CBHSQ Report*. Retrieved from Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration website: https://www.samhsa.gov/data/

Lund, I. O., & Rundmo, T. (2009). Cross-cultural comparisons of traffic safety, risk perception, attitudes and behaviour. *Safety Science*, *47*(4), 547-553. https://doi.org/10.1016/j.ssci.2008.07.008

Marcil, I., Bergeron, J., & Audet, T. (2001). Motivational factors underlying the intention to drink and drive in young male drivers. *Journal of Safety Research*, *32*(4), 363-376. https://doi.org/10.1016/S0022-4375(01)00062-7

Marowitz, L. A. (1996). *Predicting DUI (driving under the influence), volume 1: Blood alcohol concentration and driver record factors* (Report N° RSS-96-162). Retrieved from Department of Motor Vehicles' Research and Development website: https://www.dmv.ca.gov/portal/dmv-research-reports/research-studies-reports/

Martinussen, L. M., Petranca, L., & Sømhovd, M. J. (2018). The relationship between explicit and implicit attitudes towards drunk driving. *PloS One*, *13*(10), e0206124.

McBride, M., Carter, L., & Phillips, B. (2020). Integrating the theory of planned behavior and behavioral attitudes to explore texting among young drivers in the US. *International Journal of Information Management*, *50*, 365-374. https://doi.org/10.1016/j.ijinfomgt.2019.09.003

Meissner, F., Grigutsch, L. A., Koranyi, N., Müller, F., & Rothermund, K. (2019). Predicting behavior with implicit measures: Disillusioning findings, reasonable explanations, and sophisticated solutions. *Frontiers in Psychology*, *10*, 2483. https://doi.org/10.3389/fpsyg.2019.02483

Moan, I. S., & Rise, J. (2011). Predicting intentions not to "drink and drive" using an extended version of the theory of planned behaviour. *Accident Analysis & Prevention*, *43*(4), 1378-1384. https://doi.org/10.1016/j.aap.2011.02.012

Mohamed, M., & Bromfield, N. F. (2017). Attitudes, driving behavior, and accident involvement among young male drivers in Saudi Arabia. *Transportation Research Part F: Traffic Psychology and Behaviour, 47,* 59-71. https://doi.org/10.1016/j.trf.2017.04.009

Nosek, B. A., Greenwald, A. G., Banaji, M. R. (2007). The implicit association test at age 7: A methodological and conceptual review. In: J.A. Bargh (Ed.), *Social psychology and the unconscious: The automaticity of higher mental processes* (pp. 265–292). New York, NY: Psychology Press.

Parker, D., Manstead, A. S., Stradling, S. G., Reason, J. T., & Baxter, J. S. (1992). Intention to commit driving violations: An application of the theory of planned behavior. *Journal of Applied Psychology, 77*(1), 94. https://doi.org/10.1037/0021-9010.77.1.94

Potard, C., Kubiszewski, V., Camus, G., Courtois, R., & Gaymard, S. (2018). Driving under the influence of alcohol and perceived invulnerability among young adults: An extension of the theory of planned behavior. *Transportation Research Part F: Traffic Psychology and Behaviour*, *55*, 38-46. https://doi.org/10.1016/j.trf.2018.02.033

Rauch, W. J., Zador, P. L., Ahlin, E. M., Howard, J. M., Frissell, K. C., & Duncan, G. D. (2010). Risk of alcohol-impaired driving recidivism among first offenders and multiple offenders. *American Journal of Public Health, 100*(5), 919-924. https://doi.org/10.2105/AJPH.2008.154575

Rivis, A., Abraham, C., & Snook, S. (2011). Understanding young and older male drivers' willingness to drive while intoxicated: The predictive utility of constructs specified by the theory of planned behaviour and the prototype willingness model. *British Journal of Health Psychology, 16*(2), 445-456. https://doi.org/10.1348/135910710X522662

Robertson, A. A., Zhou, Q. M., Tatch, A., & Walsh, M. (2019). Gender-specific predictors of recidivism among DUI offenders. *Journal of Studies on Alcohol and Drugs*, *80*(6), 641-650. https://doi.org/10.15288/jsad.2019.80.641

Rogers, R. (Eds.). (1997). *Clinical assessment of malingering and deception (2nd ed.)*. The Guilford Press.

Rusu, A., Sârbescu, P., Moza, D., & Stancu, A. (2017). Implicit attitudes towards risky driving: Development and validation of an affect misattribution procedure for speeding. *Accident Analysis & Prevention*, *100*, 15-22. https://doi.org/10.1016/j.aap.2016.12.022

Sartori, G., Agosta, S., Zogmaister, C., Ferrara, S. D., & Castiello, U. (2008). How to accurately detect autobiographical events. *Psychological Science*, *19*(8), 772-780. https://doi.org/10.1111/j.1467-9280.2008.02156.x

Siebert, F. W., Hellmann, L., Pant, P. R., Lin, H., & Trimpop, R. (2021). Disparity of motorcycle helmet use in Nepal–Weak law enforcement or riders' reluctance?. *Transportation Research Part F: Traffic Psychology and Behaviour*, *79*, 72-83. https://doi.org/10.1016/j.trf.2021.04.005

Şimşekoğlu, Ö., Nordfjærn, T., & Rundmo, T. (2012). Traffic risk perception, road safety attitudes, and behaviors among road users: a comparison of Turkey and Norway. *Journal of Risk Research*, *15*(7), 787-800. https://doi.org/10.1080/13669877.2012.657221

Stephens, A. N., Bishop, C. A., Liu, S., & Fitzharris, M. (2017). Alcohol consumption patterns and attitudes toward drink-drive behaviours and road safety enforcement strategies. *Accident Analysis & Prevention*, *98*, 241-251. https://doi.org/10.1016/j.aap.2016.10.011

Suchotzki, K., Verschuere, B., & Gamer, M. (2021). How vulnerable is the reaction time concealed information test to faking?. *Journal of Applied Research in Memory and Cognition, 10*(2), 268-277. https://doi.org/10.1016/j.jarmac.2020.10.003

Tosi, J. D., Haworth, N., Díaz-Lázaro, C. M., Poó, F. M., & Ledesma, R. D. (2021). Implicit and explicit attitudes in transportation research: A literature review. *Transportation Research Part F: Traffic Psychology and Behaviour, 77,* 87-101. https://doi.org/10.1016/j.trf.2020.12.014

Trimboli, L., & Smith, N. (2009). *Drink-driving and recidivism in NSW* (Report N° 135). Retrieved from NSW Bureau of Crime Statistics and Research website: https://www.bocsar.nsw.gov.au/Pages/bocsar_publication/bocsar_publication.aspx

Van Dessel, P., Cummins, J., Hughes, S., Kasran, S., Cathelyn, F., & Moran, T. (2020). Reflecting on 25 years of research using implicit measures: Recommendations for their future use. *Social Cognition*, 38(Supplement), s223-s242.

Verschuere, B., Prati, V., & De Houwer, J. (2009). Cheating the lie detector: Faking in the autobiographical implicit association test. *Psychological Science, 20*(4), 410-413. https://doi.org/10.1111/j.1467-9280.2009.02308.x

Watson-Brown, N., Truelove, V., Parker, E., & Davey, J. (2021). Drink driving during the COVID-19 pandemic. *Transportation Research Part F: Traffic Psychology and Behaviour*, *78*, 369-380. https://doi.org/10.1016/j.trf.2021.02.020

Wicker, A. W. (1969). Attitudes versus actions: The relationship of verbal and overt behavioral responses to attitude objects. *Journal of Social Issues* 25, 41-78. https://doi.org/10.1111/j.1540-4560.1969.tb00619.x

World Health Organization. (2015). *Global status report on road safety 2015.* Retrieved from World Health Organization website: https://www.afro.who.int/publications

World Health Organization. (2018). *Global status report on road safety 2018.* Retrieved from World Health Organization website: https://www.afro.who.int/publications

World Health Organization. (2021). Road traffic injuries. Retrieved from https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries. Accessed on 7 September 2021.

Zhu, L. W., Zhang, Z. Y., Bao, Z. J., & Sun, Y. (2010, November). *Study on the Drink Driving Behavior of Drivers in Beijing Based on the Theory of Plan Behavior*. Paper present at the 2010 International Conference on Logistics Engineering and Intelligent Transportation Systems, Wuhan. https://doi.org/10.1109/LEITS.2010.5664935.