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DRIVING LOCUS OF CONTROL: THE CZECH ADAPTATION

VÍT GABRHEL[1], STANISLAV JEŽEK[2], PETR ZÁMEČNÍK[1]

[1] Transport Research Centre (CDV), Department of Traffic Psychology
[2] Masaryk University, Faculty of Social Studies, Department of Psychology

ABSTRACT

Objectives. This study attempts to introduce the Driving Locus of Control (DLoC), a method focused on the internal or external source of attribution of the driving behaviour, to the Czech context. This study also relates DLoC to attitudes towards autonomous vehicles (AVs).
Participants and setting. Out of the general population, 59 inquirers personally interviewed (CAPI) 1 065 respondents (49% women) in the age range between 15 and 92 years (M = 50, SD = 17). The respondents were sampled via multistage random sampling procedure, based on the list of addresses in the Czech Republic.
Hypotheses. The authors hypothesised to replicate the original two-factor structure of the DLOC Scale and that the higher levels of internal DLoC result in not considering the improvement in traffic safety as the AVs replace human drivers.
Statistical analysis. Confirmatory factor analysis was used to analyse the factor structure of DLoC Scale. Hypotheses related to the empirical validity of the method were assessed via structural equation modelling. Reliability of DLoC Scale was calculated in terms of internal consistency (McDonald coefficient).
Results. Confirmatory factor analysis revealed reasonably good support for structural validity of the one-dimensional DLoC-CZ15 factor model ($\chi2$ = 426.967, df = 90, CFI = 0.964, TLI = 0.958, SRMR = 0.066, RMSEA = 0.065). In addition, the one-dimensional DLoC-CZ15 factor model showed acceptable internal consistency - ω = 0.9 (95% CI [0.89, 0.91]). The structural equation modelling found a relationship between DLoC and some of the items capturing attitudes towards AVs, too.
Study limitations. The analysed data were obtained via interviews between respondents and inquirers. As a result, the study does not contain indicators of empirical validity measured by a methodologically different approach, such as an observation of driving behaviour.

key words:
Driving Locus of Control,
validity,
autonomous vehicles,
survey,
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klíčová slova:
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INTRODUCTION

The way that drivers operate their vehicles on roads depends not only on the physical properties of a vehicle or infrastructure, but also on the personality of a driver (Arthur et al., 1991; Iversen & Rundmo, 2002; Schwebel et al., 2006).

Driver personality is thus one of the phenomena through which traffic psychologists try to understand and explain driving behaviour (Huguenin & Rumar, 2001). Many studies use the Big 5 theoretical framework. In their meta-analysis, Clarke and Robertson (2005) concluded that there is a relationship between involvement in traffic

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Submitted: 18. 3. 2020; V. G., Transport Research Centre (CDV), Department of the Traffic Psychology, Líšeňská 2657, 636 00 Brno; e-mail: vitgabrhel@gmail.com
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accidents and higher levels of extraversion and lower levels of conscientiousness. However, both effects were small.

Traffic psychologists also focus on personality traits specific to the context of driving. Individual-differences constructs developed in or adapted to the driving context represent one of the key components of explaining phenomena like anxiety or aggression behind the wheel, compliance to norms related to driving, accident risk or sensation seeking (Ulleberg et al., 2009).

One of the personality traits used in explaining driving behaviour is driving locus of control (DLoC; Huang & Ford, 2012; Montag & Comrey, 1987). It is based on the general locus of control, a personality trait reflecting the degree to which individuals believe that they are capable of controlling events in their life. If someone sees herself as the person in control, this person exhibits the internal locus of control. Alternatively, when someone believes that external forces orchestrate events in his life, this person could be seen as having the external locus of control (Rotter, 1966). The trait is usually hypothesized as a continuous bipolar quantity where medium levels represent a belief in various mixtures of internal and external forces.

DLoC has been associated with risky driving. Specifically, Driving Internality (DI) related to cautious driving (Montag & Comrey, 1987) and alertness (Lajunen & Summala, 1995). On the other hand, Driving Externality (DE) was associated with involvement in fatal accidents (Montag & Comrey, 1987) and aggression (Lajunen & Summala, 1995). Other driving context-specific metrics like driving self-efficacy (e.g. George et al., 2007) exist. However, in this study, we focus on the Driving Locus of Control.

One of the currently highly researched questions in traffic psychology is how drivers adapt to or adopt autonomous functions of their vehicles or completely autonomous vehicles (AVs) themselves (e.g. Becker & Axhausen, 2017; Reagan et al., 2020). DLoC represents a relevant variable in this context. On a test-track, experienced drivers with an external locus of control took longer time to react to the adaptive cruise control (or ACC) failure than the drivers with the internal locus of control (Rudin-Brown & Parker, 2004) because they stayed more involved in the driving task. According to Rudin-Brown and Noy (2002), experienced drivers with the internal locus of control tend to show less trust towards automated driving systems due to their reliance on and confidence in their driving skills. Some researchers conclude that DLoC represents one of the key psychological factors behind a driver's adaptation to new in-vehicle safety technologies (Özkan & Lajunen, 2005). Later, however, Payre et al., (2014) found no correlation between external DLoC and a priori acceptability of autonomous vehicles. At the same time, they reported sampling biases in their data with respect to socio-demographic variables like gender. Thus, further evidence is needed for a more conclusive outcome, which was a part of the motivation behind our study.

The measurement of DLoC has received only limited psychometric attention so far. In the original study, Montag & Comrey (1987) developed their scale just using principal component analysis on a pool of items. No reliability indicators were provided. Following studies added only limited information on the factor structure or the internal consistency of the method (Huang & Ford, 2012) or omitted examination of psychometric properties of DLoC scale completely (Payre et al., 2014; Rudin-Brown & Noy, 2002; Rudin-Brown & Parker, 2004).

In Czech traffic psychology, there are currently only a few available measures of driver's personality. There are tests in the Vienna Test System covering areas such as readiness to take risks or aggression (Schuhfried, 2009). However, neither of the available methods address the adoption of autonomous vehicles as one of the substantial upcoming challenges for traffic psychology to tackle. In this situation, should DLoC be found psychometrically sound, it could represent a welcomed asset in the toolshed of traffic psychologists.

This study introduces Driving Locus of Control into the Czech context. The first goal of this study is to examine the psychometric properties of the measure - its factor validity and reliability in terms of internal consistency. We will test the originally proposed two-factor structure of the method, the Driving Locus of Control Scale or simply DLoCS (Montag & Comrey, 1987) in terms of factor validity. Based on the outcome, if needed, we will propose adjustments. Last but not least, we will test the internal consistency of the final solution (H1).

Moreover, we examine the ability of DLoC to predict attitudes towards autonomous vehicles in the sense of improving traffic safety as it is one of the domains often worded in relation to the introduction of AVs (e.g. Fagnant & Kockelman, 2015; Zmud et al., 2016). We hypothesize a lower subjective likelihood of using autonomous vehicles for everyday purposes in drivers with internal DLoC (H2). The hypothesis stems from the conclusion by Rudin-Brown and Noy (2002) that drivers with an internal locus of control tend to show less trust towards automated driving systems due to their reliance on and confidence in their driving skills. We use this item as an indicator of empirical validity of DLoC Scale.

We further hypothesise that the higher levels of internal DLoC result in considering unlikely to see improvements in traffic safety as the AVs replace human drivers. At the same time, respondents showing higher levels of external DLoC might not assume one of the external elements, i.e. an automated vehicle could make a difference in preventing traffic accidents. We expect a higher degree of disagreement among respondents with the more internal driving locus of control as autonomous vehicles result in less control over operating the vehicle. We assume that drivers with the internal locus of control tend to show less trust towards automated driving systems due to their reliance on and confidence in their own driving skills (H3).

Previous research on Driving Locus of Control and the relationship between this variable and attitude towards AVs (e.g. Payre et al., 2014) focused on specific subgroups of a population. In our study, we aim to include the general population as the sampling frame. Consequently, the chosen sampling procedure will produce a representative sample reflecting the socio-demographic status of the population like a more adequate proportion of men and women.

METHOD

Participants

Between November 2017 and January 2018, a survey was conducted on perceptions and attitudes related to AVs among the general population. Overall, 59 professional interviewers personally interviewed 1 065 persons older than 15 years via computer (CAPI). Respondents were selected using a multistage probabilistic sampling procedure, based on the list of address points in the Czech Republic.

In the first step, there were 74 municipalities randomly sampled throughout the Czech Republic. If there were more households per one sampling point (e.g. apartment house), in the second step, the desired number of households was randomly sampled from the list of households at the sampling point. Finally, within each of the selected households, one person older than 15 years was randomly sampled to participate in the survey.

If it was not possible to contact a household at the first trial, interviewers attempted to reach out to the household two more times within several days between each attempt. Afterwards, interviewers moved to one of the three randomly selected replacement households.

The design of the study, sampling procedure, and questionnaire were piloted on 54 individuals in October 2018.

The sample consisted of 542 (51%) men and 523 (49%) women. The average age was 50 years and the median 51 years. The most frequent category of the attained level of education was high school (434 respondents, 41% of the sample) followed by vocational education (377 respondents, 35% within the sample). The majority of respondents were economically active (760 respondents, 61% of the sample). Lastly, the most frequent income category were households with the gross monthly income of 30,001 - 50,000 CZK (or circa 1181-1966 EUR; 324 respondents, 31% of the sample). On the other hand, only 2% (22 respondents) of the participants declared household gross monthly income less than 361 EUR. Most respondents (921, 86.5% of the sample) held a driving licence. Due to the fact that DLoC relates to self-perception, non-drivers were removed from any DLoC-related analyses. Table 1 provides more detailed information regarding the socio-demography of the participants:

Table 1 Socio-demography of the sample

Socio-demography of the sample	Category	Sample n = 1 065
Gender	Man	542 (51%)
	Woman	523 (49%)
Age (in years)	M (SD)	50 (17)
	Median	51
	Range	15 – 90
Level of education	Primary	72 (7%)
	Vocational	377 (35%)
	High school	434 (41%)
	College	182 (17%)
Economic activity	Economically active	760 (61%)
	Economically inactive	305 (29%)
Household gross monthly income	Less than 9,200 CZK	22 (2 %)
	9,201 - 15,000 CZK	132 (12 %)
	15,001 - 22,000 CZK	193 (18 %)
	22,001 - 30,000 CZK	311 (29 %)
	30,001 - 50,000 CZK	324 (31 %)
	More than 50,000 CZK	83 (8 %)
Driving licence?	Driving Licence	921 (86.5%)
	No driving Licence	144 (13.5%)

Note: For a reference, the average monthly gross income for individuals was 29504 CZK or circa 1180 EUR (CSO, 2018).

Measures

The interview itself focused on issues associated with AVs or related topics such as attitudes towards new technology in general or a respondent's travel behaviour.

Driving Locus of Control Scale is a Czech adaptation of the measure developed by Montag and Comrey (1987). Respondents answered the 30 Likert-type items with a 6-point response scales with the following verbal anchors: "*Strongly disagree*", "*Rather disagree*", "*Somewhat disagree*", "*Somewhat agree*", "*Rather agree*", and "*Strongly agree*". Half of the items tap the facet of a driver's External Driving Locus of Control (e.g. "*A driver does not have control over what is happening on the road.*"). The other half taps the Internal Driving Locus of Control (e.g. "*Accidents occur because drivers have not learned to drive carefully.*"). The measure was developed in Israel in an effort to identify personality characteristics associated with causing traffic accidents. So, the content of items focuses mainly on attributing the cause of traffic-related accidents. The Driving Locus of Control Scale was subsequently adapted to other countries and contexts, such as changing driving behaviour in the USA (Huang & Ford, 2012) or attitudes towards AVs (Payre et al., 2014; Rudin-Brown & Noy, 2002; Rudin-Brown & Parker, 2004). DLoC was translated to Czech using a translation back-translation procedure (Hambleton, 1994).

At the beginning of the interview, respondents received a vignette regarding the topic of AVs: "*An autonomous vehicle controls all steering functions while driving. For example, cornering, braking or acceleration. An autonomous vehicle can handle driving in both motorway and inhabited areas. It can also park itself. The 'operator' of an autonomous vehicle enters a destination or specifies the route that the vehicle should travel. If necessary, the 'operator' can take control of the control, for example, in very bad weather conditions. An autonomous vehicle is not science fiction. Autonomous vehicles are likely to be available on the market within five to eight years.*"

Subjective likelihood of using autonomous vehicles – respondents were asked to evaluate to what extent they considered it likely that they would use autonomous vehicles for their everyday needs (e.g. travelling to work or shopping) on a four-point Likert-like scale. The respondents could choose exactly one of the following verbal anchors: "*Very unlikely*", "*Rather unlikely*", "*Rather likely*", and "*Very likely*".

The significant presence of traffic safety theme in DLoC was reflected in our choice of the other indicators of empirical validity:

Perceived benefits of the AVs introduction – respondents answered a question "*How likely do you think it is that the following benefits will occur when using AVs?*" in four instances ("*Fewer crashes.*", "*Reduced severity of crashes*", "*Improved safety for pedestrians*", and "*Improved safety for cyclists*"). Respondents indicated on a four-point rating scale how likely they think AVs would bring a benefit in question (*"Very likely"*, *"Somewhat likely"*, *"Somewhat unlikely"*, *"Very unlikely"*).

The automated driving system would provide me with safety compared to manual driving. When answering this item, respondents chose from one of the seven points on the rating scale. The lowest ("*1*") and the highest ("*7*") values contained verbal anchors (*"I strongly disagree"* and *"I strongly agree"*).

Statistical analysis[1]

Data were analysed using statistical package R (version 3.6.1; R Core Team, 2019) The dplyr package (version 0.8.3; Wickham et al., 2019) was used for data wrangling.

[1] Data, code, and supplement materials such as figures are publicly accessible in the following repository: https://github.com/VGabrhel/DLoC-CZ15

We used confirmatory factor analysis to test factor structures of DLoCS via the lavaan (version 0.6-5; Rosseel, 2012) library. The same analytical tools were used to test the proposed structural model, containing hypothesised relationships between DLoCS and the hypothesised indicators of the empirical validity of DLoCS. The same analytical tools were also used to calculate reliability in terms of internal consistency (omega coefficient; Raykov, 1997). The matrix of polychoric correlations was visualised using corrplot (Wei & Simko, 2017) package and lavaanPlot (Lishinskij, 2018) produced the structural diagram.

RESULTS

Descriptive statistics

When asked how probable it is that they would use an automated vehicle for their everyday mobility, 63% of respondents saw this as something very or somewhat unlikely.

When it comes to the expected benefits of AVs, more than 50% of respondents associate wide usage of AVs with better traffic safety. This results in an expectation of fewer car accidents (63% of respondents chose either "*Somewhat likely*" or "*Very likely*") or their reduced severity (63% of respondents), but also in the expected improvement of traffic safety for pedestrians (66% of respondents) and cyclists (66% of respondents).

Also, 42.2% of the participants (n = 449) tended to agree with the statement "*The automated driving system would provide me with safety compared to manual driving*". On the other hand, 24.7% of the sample (i.e. 262) chose the neutral value, and 33.1% (i.e. 351 respondents) disagreed.

As for DLoCS, usually, less than 20% of all respondents took one of the extreme positions on the continuum.

Tables 2 and 3 provide more detailed information regarding the items related to the attitudes towards autonomous vehicles as well as DLoCS.

Before proceeding to the CFA, polychoric correlations between individual items were computed. In line with the research of Montag and Comrey (1987), manifest variables depicting externality and internality facets of DLoCS were negatively correlated. At the same time, some items from the same domain showed correlation values close to zero [e.g. DE_03 ("*The driver can do nothing more than drive according to traffic regulations.*") and DE_13 ("*It is difficult to prevent accidents in bad conditions such as darkness, rain, narrow roads, curves, and so on.*") or DI_11 ("*Accidents happen when the driver does not take into consideration all the possible behaviours of pedestrians.*") and DI_15 ("*Prevention of accidents depends only on the driver and his characteristics rather than on external factors.*"]. Figure 1 (accessible via https://github.com/VGabrhel/DLoC-CZ15/blob/master/Figure%201.png) shows the relationships between each of DLoCS items.

Factor validity and internal consistency of DLoCS

Due to the categorical nature of the individual items, the two correlated factor model proposed by Montag and Comrey (1987) was estimated using Diagonally Weighted Least Squares estimator with items modeled as ordinal (Model 1). The model was specified with correlated factors even though the original factor analyses were done with orthogonal rotation.

Model 1

Fit indices such as χ^2/df či RMSEA (Byrne, 2006) indicate relatively poor fit between the model and data as the ratio between $\chi 2$ and df is 7.58 and RMSEA ranges between

Table 2 Attitudes towards autonomous vehicles

Perceived benefits of the CAVs introduction	Very unlikely	Somewhat unlikely		Somewhat likely		Very likely	
Fewer crashes	104 (9.9%)	278 (26.4%)		520 (49.5%)		149 (14.2%)	
Reduced severity of crashes	102 (9.7%)	297 (28.2%)		499 (47.3%)		156 (14.8%)	
Improved safety for pedestrians	102 (9.8%)	249 (23.8%)		463 (44.2%)		232 (22.2%)	
Improved safety for cyclists	104 (9.9%)	249 (23.7%)		473 (45.1%)		223 (21.3%)	
(I strongly disagree - I strongly agree)	**1**	**2**	**3**	**4**	**5**	**6**	**7**
The automated driving system would provide me with safety compared to manual driving	128 (12%)	91 (8.6%)	132 (12.4%)	262 (24.7%)	152 (14.3%)	111 (10.4%)	186 (17.5%)
Likelihood of using an AV	Not at all likely	Somewhat unlikely		Somewhat likely		Extremely likely	
What is the likelihood that you would ride in a self-driving vehicle for everyday use?	283 (26.6%)	387 (36.3%)		316 (29.7%)		79 (7.4%)	

Note: n of the sample = 1 065

0.084 and 0.09 (90% C.I.). Also, the values of the TLI (0.863) or CFI (0.872) does not allow us to conclude that the model and the data match nearly identically (Holmes-Smith et al., 2006). At the same time, values of these indicators of goodness of fit are close to the usual thresholds indicating satisfying fit indices. Most items had adequate loadings (the lowest value was 0.25, the highest 0.74) and thus indicate the items measure the latent variable well.

On the other hand, the null model RMSEA is 0.084 reflecting the low average intercorrelations of items and thus our model RMSEA is less informative (Kenny, 2019). Moreover, both latent variables correlate quite substantially (-0.742). Modification indices suggest relatively strong correlations between some of the manifest variables.

All in all, the presented results indicate that the model may fit the data in some aspects, but also that there is room for improvement. Content of the items constituting DLoCS reflects three major domains or facets: a) Externality – external factors that make it difficult/impossible to prevent traffic accidents ("*It is very hard to prevent accidents involving pedestrians who come out from between parked cars*."), b) Internality - accidents are preventable by the characteristics or behaviour of a driver ("*Accident-free driving is a result of the driver's ability to pay attention to what is happening on the roads and sidewalks.*"), and c) Internality - accidents that happened could have been prevented by the characteristics or behaviour of a driver (DI_02 or "*When a driver is involved in an accident, it is because he did not drive as he should*."). Understandably, items within the same facet correlate substantially (e.g. DE_08 and DE_09: 0.77; or DI_02 and DI_03: 0.72). In addition, modification indices suggest that allowing correlation between items like DI_02 and DI_03 (or "*When a driver is involved in an accident it is because he did not pay attention to his driving.*") would substantially increase fit between the model and the data. Consequently, there is both theoretical as well as empirical evidence for reducing the number of items from the same facet. Also, some of the items were removed as they point somewhat outside the Driving Locus of Control as a construct (e.g. DE_03: "*The driver can do nothing more than drive according to traffic regulations.*"). By applying these criteria, we arrived at the 15 manifest variables (DE - 02, 04, 06, 08, 12, 13, and 15; DI - 03, 04, 06, 08, 09, 10, 11, and 12).

Also, as there was a substantial relationship between both latent variables (standardized factor loading = -0.742), there is a psychometric argument for using a single-factor model containing two polarities - internality and externality of driving.

Model 2

The second model, containing only 15 manifest variables (DE - 02, 04, 06, 08, 12, 13, and 15; DI - 03, 04, 06, 08, 09, 10, 11, and 12) and single factor resulted in more favourable values of fit indices. First of all, CFI and TLI was above 0.95 and SRMR was under 0.08, the cut-off values suggesting adequate fit between data and a model. RSMEA also indicates an acceptable level of fit between model and data (0.065).

Item loadings (min = 0.38; max = -0.75) suggest that the reduced set of items measures the single-factor DLoCS well. This is further supported by the relatively high internal consistency, which estimated by McDonald's ω was 0.90 (95% CI [0.89, 0.91]). Measurement invariance on the factor loadings level was found between men and women (χ^2 (194) = 983.5, p = 0.80, CFI = 0.816, RMSEA = 0.095), but not when it comes to intercepts (χ^2 (208) = 1012.49, p = 0.01, CFI = 0.812, RMSEA = = 0.093). Equal loadings (χ^2 (194) = 1028, p = 0.06, CFI = 0.805, RMSEA = 0.098) and intercepts (χ^2 (208) = 1044.9, p = 0.26, CFI = 0.804, RMSEA = 0.095) were observed among two age groups based on the median age (i.e. 50 years).

Table 4 Fit between proposed DLoC model and the data

Model	χ^2	df	χ^2 /df	CFI	TLI	SRMR	RMSEA
1)*	3062.644	404	7.58	0.872	0.863	0.093	0.084
2)**	426.967	90	4.74	0.964	0.958	0.066	0.065
3)***	552.002	216	2.556	0.964	0.960	0.048	0.038

Note. *n = 878; **n = 898; ***n = 871. The variation in n is caused by including more variables with more missing values into the model. χ^2 /df = Normed χ^2; CFI = Comparative Fit Index; TLI = Tucker Lewis Index; SRMR = Standardized Root Mean Square Residual); RMSEA = Root-Square Error of Approximation.

Associations of DLoCS with AV related attitudes

Model 3

The final SEM model contained both DLoCS and the attitudes and beliefs related to autonomous vehicles. From the point of the model fit, SEM resulted in worse fit indices in some regards (e.g. CFI) and better in others (e.g. SRMR) in comparison to the model used in the CFA. In conclusion, the model still fits adequately to the data. The following structural diagram (Figure 2) depicts the structure of the model as well as standardized factor loadings/regression coefficients along with the level of statistical significance (**p < 0.01; ***p < 0.001).

All of the empirical validity indicators entered in one block, allowing for holding other variables constant when interpreting coefficients of a given variable. There was no substantial relationship found between DLoCS and subjective likelihood of using

Table 3 Driving Locus of Control Scale (DLoC-S)

Driving Locus of Control	Disagree very much	Disagree quite a bit	Disagree some	Agree a little	Agree quite a bit	Agree very much
01. (DE_01) Driving with no accidents is mainly a matter of luck.	119 (12.9%)	154 (16.7%)	113 (12.3%)	295 (32.1%)	178 (19.3%)	61 (6.6%)
02. (DE_02) Accidents happen mainly because of different unpredictable events.	31 (3.4%)	139 (15.2%)	168 (18.3%)	237 (25.8%)	239 (26.1%)	103 (11.2%)
03. (DE_03) The driver can do nothing more than drive according to traffic regulations.	16 (1.7%)	52 (5.7%)	117 (12.7%)	171 (18.6%)	215 (23.4%)	349 (37.9%)
04. (DE_04) Accidents happen because of so many reasons we will never know the most important one.	50 (5.4%)	169 (18.4%)	161 (17.5%)	220 (24%)	208 (22.7%)	110 (12%)
05. (DE_05) People who drive a lot with no accidents are merely lucky; it is not because they are more careful.	147 (16%)	227 (24.7%)	193 (21%)	166 (18.1%)	145 (15.8%)	41 (4.5%)
06. (DI_01) The careful driver can prevent any accident.	45 (4.9%)	127 (13.8%)	161 (17.5%)	211 (22.9%)	258 (28%)	119 (12.9%)
07. (DI_02) When a driver is involved in an accident, it is because he did not drive as he should.	39 (4.2%)	151 (16.4%)	182 (19.8%)	238 (25.9%)	223 (24.2%)	87 (9.5%)
08. (DI_03) When a driver is involved in an accident it is because he did not pay attention to his driving.	54 (5.9%)	168 (18.2%)	196 (21.3%)	207 (22.5%)	220 (23.9%)	76 (8.3%)
09. (DI_04) Accidents are only the result of mistakes made by the driver.	71 (7.7%)	207 (22.6%)	221 (24.1%)	196 (21.4%)	161 (17.6%)	61 (6.7%)
10. (DI_05) The driver is to be blamed almost always when an accident occurs.	37 (4%)	129 (14%)	187 (20.3%)	234 (25.4%)	228 (24.8%)	105 (11.4%)
11. (DE_06) It is difficult to prevent accidents in bad conditions such as darkness, rain, narrow roads, curves, and so on.	37 (4%)	163 (17.7%)	198 (21.5%)	235 (25.5%)	208 (22.6%)	79 (8.6%)
12. (DE_07) Most accidents happen because of bad roads, lack of appropriate signs, and soon.	54 (5.9%)	208 (22.6%)	205 (22.3%)	254 (27.6%)	144 (15.7%)	55 (6%)
13. (DE_08) It is very hard to prevent accidents involving pedestrians who come out from between parked cars.	28 (3%)	82 (8.9%)	142 (15.4%)	191 (20.8%)	226 (24.6%)	251 (27.3%)
14. (DE_09) Accidents in which children are involved are hard to prevent because they do not know how to be careful.	33 (3.6%)	91 (9.9%)	135 (14.7%)	226 (24.6%)	233 (25.3%)	202 (22%)
15. (DE_10) It is very hard to prevent accidents in which old people are involved because they cannot hear nor see well.	23 (2.5%)	84 (9.2%)	109 (11.9%)	315 (34.5%)	229 (25.1%)	154 (16.8%)
16. (DI_06) Accidents happen because drivers have not learned how to drive carefully enough.	103 (11.2%)	241 (26.3%)	235 (25.6%)	203 (22.1%)	110 (12%)	25 (2.7%)
17. (DI_07) It is always possible to predict what is going to happen on the road and so it is possible to prevent almost any accident.	60 (6.5%)	107 (11.6%)	232 (25.2%)	215 (23.4%)	210 (22.9%)	95 (10.3%)

Driving Locus of Control	Disagree very much	Disagree quite a bit	Disagree some	Agree a little	Agree quite a bit	Agree very much
18. (DI_08) Accidents happen when the first driver does not take into consideration all the possible actions of the second driver.	89 (9.7%)	182 (19.8%)	237 (25.8%)	186 (20.3%)	185 (20.2%)	39 (4.2%)
19. (DI_09) Accidents happen because the driver does not make enough effort to detect all sources of danger while driving.	103 (11.2%)	246 (26.8%)	263 (28.6%)	169 (18.4%)	110 (12%)	27 (2.9%)
20. (DI_10) Most accidents happen because of lack of knowledge or laziness on the part of the driver.	60 (6.6%)	192 (21%)	253 (27.7%)	182 (19.9%)	181 (19.8%)	47 (5.1%)
21. (DE_11) If you are to be involved in an accident, it is going to happen anyhow, no matter what you do.	117 (12.8%)	188 (20.5%)	196 (21.4%)	227 (24.8%)	127 (13.9%)	60 (6.6%)
22. (DE_12) Most accidents happen because the second driver does not pay attention to traffic regulations even when the first driver does.	30 (3.3%)	156 (17%)	172 (18.7%)	204 (22.2%)	230 (25%)	127 (13.8%)
23. (DE_13) The driver does not have enough control over what happens on the road.	60 (6.5%)	199 (21.7%)	183 (19.9%)	198 (21.5%)	198 (21.5%)	81 (8.8%)
24. (DE_14) Most accidents happen because of mechanical failures.	99 (10.8%)	298 (32.5%)	217 (23.7%)	185 (20.2%)	82 (8.9%)	36 (3.9%)
25. (DE_15) There will always be accidents no matter how much drivers try to prevent them.	33 (3.6%)	119 (13%)	160 (17.4%)	232 (25.3%)	239 (26%)	135 (14.7%)
26. (DI_11) Accidents happen when the driver does not take into consideration all the possible behaviors of pedestrians.	113 (12.3%)	226 (24.7%)	263 (28.7%)	167 (18.3%)	124 (13.6%)	22 (2.4%)
27. (DI_12) Accident-free driving is a result of the driver's ability to pay attention to what is happening on the roads and sidewalks.	147 (16%)	256 (27.9%)	220 (24%)	169 (18.4%)	109 (11.9%)	17 (1.9%)
28. (DI_13) The driver can always predict what is going to happen; that is why there is no room for surprises on the road.	31 (3.4%)	116 (12.6%)	214 (23.3%)	234 (25.5%)	222 (24.2%)	101 (11%)
29. (DI_14) It is possible to prevent accidents even in the most difficult conditions such as narrow roads, darkness, rain, and so on.	50 (5.5%)	241 (26.4%)	262 (28.7%)	200 (21.9%)	121 (13.2%)	40 (4.4%)
30. (DI_15) Prevention of accidents depends only on the driver and his characteristics rather than on external factors.	35 (3.8%)	134 (14.6%)	245 (26.7%)	225 (24.6%)	193 (21.1%)	84 (9.2%)

Note: n of the sample = 921. "DE" stands for the "Driving Externality" or "External Driving Locus of Control", "DI" for the "Driving Internality" or "Internal Driving Locus of Control". As items associated with DE and DI rotate after the count of five, each of the items in the table has attached not only its rank within the method as such, but also in the respective dimension. For example, "DI_13" represents an item depicting internal DLoC number 13.

AVs (β = -0.016; p = 0.69). The same applies for two of the expected benefits of increasing traffic safety by introducing AVs: fewer crashes (β = -0.029; p = 0.603) and improved safety for pedestrians (β = -0.059; p = 0.119). Finally, a standard deviation increase in agreeing that an automated driving system would provide more safety compared to manual driving is non-significantly associated with a 0.043 standard deviation increase in DLoCS (p = 0.305).

On the other hand, a standard deviation increase in expecting less severe crashes is associated with a 0.214 standard deviation increase in DLoCS (p < 0.001). Also, a standard deviation increase in expecting improved safety for cyclists is associated with a 0.244 decrease in DLoCS (p < 0.001).

As for the control variables, there was no relationship found in the sample between men and women (β = -0.043; p = 0.305) or respondents with different educational levels (β = -0.055; p = 0.119). In comparison, a standard deviation increase in age is associated with a 0.163 standard deviation increase in DLoCS (p < 0.001). Finally, respondents with higher educational attainment tended to, on average, score lower on the DLoCS (β = -0.075; p = 0.042). At the same time, the effect size for both of these control variables is rather small.

Table 5 contains a more detailed overview of the regression coefficients in the Model 3.

Table 5 Regression of the empirical validity indicators and single-factor DLoC

Variable	Estimate	Std. Err	z-value	p	β
Likelihood of using AVs	-0.009	0.022	-0.399	0.69	-0.016
Fewer crashes	-0.018	0.034	-0.521	0.603	-0.029
Less severe crashes	0.129	0.035	3.684	<0.001	0.214
Improved safety for pedestrians	0.068	0.036	1.887	0.059	0.119
Improved safety for cyclists	-0.139	0.038	-3.68	<0.001	-0.244
Perceived safety - AVs vs. manual	0.012	0.011	1.026	0.305	0.043
Age	0.005	0.001	4.261	<0.001	0.163
Gender	-0.042	0.037	-1.134	0.257	-0.041
Education	-0.036	0.018	-2.037	0.042	-0.075

Note. n = 852

DISCUSSION

The original two-factor structure of DLoCS with one factor for each pole of the externality-internality continuum did not show a satisfying fit with the data in the Czech context. The items would have to be substantially improved to create a two-dimensional model that the original authors intended. Rather than trying to improve the two-factor model we chose to build an anidimensional model which would better reflect that theoretically internality-externality is a single continuum.

Using single-factor structure makes sense from the theoretical as well as psychometric perspective. In the original paper, Montag and Comrey (1987) used varimax rotation method, thus assuming externality and internality of driving to be

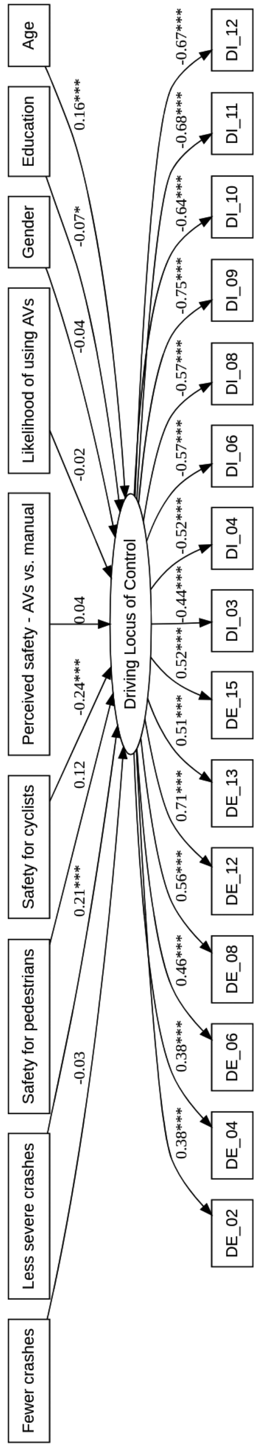

Figure 2 Structural diagram of the model

independent. However, two facets of the same construct could be hardly expected to be independent of each other. Strong correlation in this study supports using the scale in a single-factor form. Conclusions of this study corroborates contemporary studies on the locus of control that work with a single-factor scale (e.g. Struijs et al., 2020).

Moreover, as the content of the items overlaps significantly in many instances [e.g. (DI_12) "*Accident-free driving is a result of the driver's ability to pay attention to what is happening on the roads and sidewalks*." and (DI_13) "*The driver can always predict what is going to happen; that is why there is no room for surprises on the road.*"], it only makes sense to reduce the number of such items without having a negative impact on the content validity of DLoCS. Also, some of the items were removed as their content diverts from the conceptualisation of DLoC. For example, the item (DE_03) "*The driver can do nothing more than drive according to traffic regulations."* offers an interpretation related to the norm subjection rather than the inevitable impact of external forces.

A unidimensional model based on a subset of 15 items from both original dimensions resulted in reasonably good fit with our data. All items loaded substantially to the single DLoC factor, yet the factor loadings were reasonably high not to converge towards singular covariance matrix. We suggest calling this abbreviated version DLoC-CZ15. Reliability in terms of internal consistency is sufficient for the use of a summation score. Despite using only half of the items while staying faithful to the content of DLoC, the internal consistency remained quite high. This outcome is positive from the practical point of view as it substantially reduces administration time of DLoCS.

As for the associations with AV-related beliefs and attitudes, an increase in DLoCS towards externality of driving associated with a lower expectation of less severe car crashes after introducing AVs. This outcome is aligned with the expectation that respondents showing higher levels of external DLoC might not assume one of the external elements, i.e. an automated vehicle could make a difference in preventing traffic accidents. Alternatively, a tendency towards the driving internality correlated with a higher expectation of the less severe car crashes after introducing AVs. This finding supports the role of Driving Locus of Control (or Locus of Control in general) in the context of the attribution theory (e.g. Weiner, 1992). Here, an individual with showing driving internality identifies the cause of dealing with various situations on the road in himself or herself. On the other hand, traffic accidents may appear to be caused by other drivers' lack of skills and other driver-related qualities. From the perspective of a person displaying a high level of driving internality, traffic accidents are caused by other drivers' failures. Consequently, if traffic accidents happen because of other drivers' failures, something like AVs, which could prevent traffic accidents from happening in the first place, can be seen as a way of increasing traffic safety.

Moreover, subjectively declared likelihood of using AVs was not related to either externality nor internality of driving. In this regard, results in this study corroborate findings of Payre et al. (2014). This may come as a surprise especially among respondents with a higher degree of driving internality, as we assumed that drivers with the internal locus of control would show less trust towards automated driving systems due to their reliance on and confidence in their own driving skills (Rudin-Brown & Noy, 2002).

Last but not least, this study has its limitations. The analysed values were obtained via interviews between respondents and inquirers. As a result, the study does not contain indicators of empirical validity measured through a methodologically different approach, such as an observation of driving behaviour. This could be also seen as an opportunity for the next research direction. For example, DLoC could be applied in the context of rehabilitation among drivers who had their driving licences withdrawn because of their drink driving (Šucha et al., 2017). Here, driving internality could be interpreted as over-confidence in a capacity of a driver to handle risky driving such as driving under the influence of alcohol.

Despite the described limitations, this study allows us to conclude that DLoC is a method plausible to use in the Czech traffic psychology.

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SOUHRN

Driving Locus of Control: adaptace metody do českého kontextu

Problém. Tato studie uvádí Driving Locus of Control (DLoC), metodu zaměřenou na atribuovaný zdroj chování při řízení, do českého kontextu. Dále pak tato studie ověřuje vztah DLoC k postojům k autonomním vozidlům (AV).

Metoda. 59 tazatelů osobně oslovilo (metoda CAPI) 1 065 respondentů z obecné populace (49% žen) ve věkovém rozmezí od 15 do 92 let (M = 50, SD = 17). Respondenti byli vybráni pomocí vícestupňového náhodného výběru na základě seznamu adres v České republice.

Hypotézy. Autoři předpokládali replikaci původní dvoufaktorové struktury škály DLoC. Současně předpokládali, že vyšší úroveň interního DLoC nesouvisí s očekáváním zlepšení bezpečnosti provozu, když AV nahradí lidské řidiče.

Analýza dat. K analýze faktorové struktury metody byla použita konfirmační faktorová analýza. Hypotézy týkající se empirické validity metody byly ověřeny pomocí strukturního modelování. Reliabilita škály DLoC ve smyslu vnitřní konzistence byla vypočítána pomocí McDonaldova koeficientu.

Výsledky. Konfirmační faktorová analýza přinesla adekvátní podporu strukturní validity jednorozměrného faktorového modelu DLoC-CZ15 (χ^2 = 426,967, df = 90, CFI = 0,964, TLI = 0,958, SRMR = 0,066, RMSEA = 0,065). Navíc jednorozměrný faktorový model DLoC-CZ15 vykázal přijatelnou vnitřní konzistenci – ω = 0,9 (95% CI [0,89; 0,91]). V rámci strukturního modelování byla zjištěna souvislost mezi DLoC a částí položek zachycujících postoje k AV.

Limity studie. Analyzovaná data byla získána prostřednictvím rozhovorů mezi respondenty a tazateli. V důsledku toho studie neobsahuje indikátory empirické validity měřené metodologicky odlišným přístupem, například pozorováním chování při řízení.