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Published in:
Transportation Research Procedia

Link to article, DOI:
[10.1016/j.trpro.2017.05.065](https://doi.org/10.1016/j.trpro.2017.05.065)

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

Citation (APA):
Bortei-Doku, S., Kaplan, S., Prato, C. G., & Nielsen, O. A. (2017). Road signage comprehension and overload: The role of driving style and need for closure. *Transportation Research Procedia*, 24, 442-449. DOI: 10.1016/j.trpro.2017.05.065

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3rd Conference on Sustainable Urban Mobility, 3rd CSUM 2016, 26 – 27 May 2016, Volos, Greece

Road signage comprehension and overload: the role of driving style and need for closure

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Abstract

This study looks at the provision of information via traffic signs and its relation with driving styles, need for closure and socio-economic characteristics of road users. A web-based questionnaire allowed collecting information about traffic signs and road surface markings in 12 traffic locations that were presented in two variations: (i) in the first 6 cases, a first configuration contained information that led to ambiguity about the manoeuvres that were legal and a second configuration added traffic signs to eliminate the ambiguity; (ii) in the second 6 cases, a first configuration presented the road environment without signs and a second configuration added traffic signs to verify information redundancy. Respondents indicated for each location which manoeuvres they deemed legal and how many conflicts they estimated without traffic signs, and safety perception and comfort level improved with the traffic signs. Moreover, respondents reported their socio-economic characteristics and filled two questionnaires about need for closure and driving styles. Completed questionnaires from 753 participants from Hungary with expertise in transport and traffic were analysed via statistical and factor analysis, and results reveal that: (i) road users are heterogeneous in their perception and processing of information, as the number of manoeuvres correctly identified as legal relates to their socio-economic characteristics; (ii) the perception of improvements after the provision of information relates also to the road users' socio-economic characteristics and their driving style and need for closure; (iii) different amounts of information are sufficient for different road users not to feel uncertain regarding manoeuvres being legal at a certain traffic location.

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Peer-review under responsibility of the organizing committee of the 3rd CSUM 2016.

Keywords: Need For Closure Scale; Multidimensional Driver Style Inventory; information; driver behavior; traffic signs

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1. Introduction

As traffic conflicts are a major cause of serious and fatal injuries, and 90% of them are attributed to behavioural causes, it is essential to approach their analysis with an anthropocentric approach. This study looks at the provision of information via traffic signs and its relation with driving styles and cognitive approaches in order to understand whether a safe minimum information level exists for drivers and what this level relates to.

Existing research on traffic signs and surface markings has focused on their effect as stand-alone items rather than parts of a complex system with the road users and the road environment. Although countries have largely agreed on the basics of shape, layout, colour schemes and marking configurations (UNECE, 1968), road agencies around the world have applied different rules that vary in particular on the maximum amount of traffic signs allowed on a pole

(e.g., one for New Zealand, two for the United Kingdom, three for Hungary). Researchers have looked into the traffic signs and markings to investigate the effect of ergonomic principles (Ben-Bassat and Shinar, 2006; Ng and Chan, 2008), background colour (Liu et al., 2010), and symbol and text mixture (Shinar and Vogelzang, 2013). Moreover, researchers have looked at the provision of information to analyse the effect of amount (Liu, 2005; Lai, 2011; Shalloe et al., 2014), multiple message configuration (Castro et al., 2008), and placement (Borowsky et al., 2008; Liu and Lu, 2013; Zhao et al., 2014), as well as their comprehensibility as a function of road users' characteristics (Al-Madani and Al-Janahi, 2002a, 2002b; Ng and Chan, 2007). Lastly, researchers have looked at the potential for distraction when traffic signs are alongside commercial advertisements (Young et al., 2009; Bendak and Al-Saleh, 2010; Edquist et al., 2011) or contain commercial content (Metz and Kruger, 2013).

This study concentrates in particular on the amount of information that plays a crucial role in the traffic context. Existing research demonstrates that too much information may be a problem, as the efficiency cognition of drivers has been shown to decrease with an increase in the amount of information provided (Liu, 2005; Liu et al., 2011), and the provision of traffic signs along a route has been proven not informative as drivers read only 25% of the signage while driving (Costa et al., 2014). These findings are not surprising when thinking about the working memory theory (Baddeley and Hitch, 1986) about the existence of a central executive mechanism in the human mind that can only distribute attention as a limited resource, that has led the US Department of Transportation to mention that too much information in the traffic environment might lead to complete disregard of all the traffic signs (FHWA, 2009). Existing research shows also that too little information may be a problem, as the less information is provided, the more drivers rely on their own knowledge of traffic laws as well as their judgment. Ambiguous scenarios create uncertainty that may lead to undesirable coping mechanisms from distractedness to aggression (Gwyther et al., 2014).

As the amount of information plays a crucial role, this study looks at the relationship between road user, road environment and traffic signs from an anthropocentric perspective. The assumption is that road users process information in a heterogeneous manner because of different characteristics, as shown by existing research focusing on the Need for Closure cognitively (Webster and Kruglanski, 1994) that can be linked to the way people process information (Kossowska et al., 2013), recall information accurately (Dijksterhus et al., 1996) or deal with uncertainty by utilizing coping mechanisms (Czernatowitz-Kukuczka et al., 2014).

This study looks at how road users process road signs and the road environment by proposing a web-based questionnaire where the participants were required to answer questions about traffic signs and road surface markings in 12 traffic locations that were presented in two variations: (i) in the first 6 cases, a first configuration contained information that led to ambiguity about the manoeuvres that were allowed and a second configuration added information to eliminate the ambiguity; (ii) in the second 6 cases, a first configuration presented the road environment without signs and a second configuration introduced traffic signs that led to verify whether redundancy existed. For each location, respondents not only indicated which manoeuvres they deemed legal, but also how they perceived safety, how they perceived the setting comfortable, and how the second configuration helped in improved the perceived safety. Moreover, the questionnaire collected information about driving styles via the Multidimensional Driver Style Inventory (MDSI, Taubman – Ben-Ari et al., 2004) and need for cognitive closure via the Need for Closure Scale (NFCS, Webster and Kruglanski, 1994).

2. Methods

2.1 Survey design and administration

The survey design relied on three hypotheses: (i) road users are heterogeneous in terms of perceiving and processing information, which affects their decision making and comfort level while driving; (ii) the perception of safety by road users is correlated with the amount of information in the road environment; (iii) a different amount of information for each road user is sufficient not to feel uncertain regarding manoeuvres being legal at a certain traffic location.

The locations for the survey were selected according to two criteria: (i) the first 6 cases needed ambiguity regarding the layout and the geometry so that additional traffic signs would remove the uncertainty about the legal manoeuvres; (ii) the second 6 cases needed an environment where the traffic signs were providing information that appeared quite obvious from the layout and the geometry. The locations were selected from Google Street view (please refer to the examples in Figure 1 and 2), and were digitally corrected to eliminate image rendering issues. Two variants for each location were then created: for the first 6 locations, the location did not contain information and was open to ambiguity

(Figure 1 left), and then traffic signs were digitally added to remove ambiguity (Figure 1 right); for the second 6 locations, the information was removed from the original picture to examine redundancy (Figure 2 left), and then the original picture was presented (Figure 2 right). Given the characteristics of traffic signs, the first 6 locations were taken from Denmark where a lower number of signs is allowed by the road authorities, while the second 6 locations were taken from Hungary where a higher number of signs is allowed by the road authorities.



Figure 1. Example of the first 6 locations with (left) the configuration without traffic signs, and (right) the configuration with traffic signs.



Figure 2. Example of the second 6 locations with (left) the configuration without traffic signs, and (right) the configuration with traffic signs.

The participants were presented the first 6 locations in the two configurations described. In the first configuration, they were asked to answer whether certain manoeuvres from the various lanes were legal and to estimate the frequency of traffic conflicts in the past 5 years over a 7-point Likert scale ranging from “never” to “always”. In the second configuration, they were asked to rate the improvement in perceived safety and to express their comfort level with the new configuration after the elimination of the ambiguity. The participants were then presented the second 6 locations in the two configurations described, and they were asked the same questions concerning legal manoeuvres and safety perceptions for the first configuration, and safety improvements and comfort level for the second configuration. It should be noted that it was decided not to provide variants of the same location, in order to avoid a learning effect by the participants, and not to suggest that more information is always related to more legal manoeuvres, in order to avoid an anchoring effect by the participants.

The participants also answered socio-economic questions about age, gender, place of residence, income, driving frequency, alongside the level and nature of relevant professional experience and field experience. Most importantly, the participants filled an NFCS short version (Roets and Van Hiel, 2011) that was adapted to the traffic context and a MDSI short version (Taubman – Ben-Ari et al., 2004) that was adapted to the context of perception of information. The items for the scales are presented in Table 1.

Table 1. Items in the NFCS and MDSI scales

Scale	Item
NFCS	I1 When I have made a traffic decision, I feel relieved

	I2	I don't like traffic situations that are uncertain
	I3	I think paying close attention to traffic signs and keeping regulations is very important
	I4	I find that a well ordered travel routine with regular hours suits my temperament
	I5	I feel uncomfortable when I don't know the reason for a traffic regulation
	I6	I don't like to take a new route without knowing what I can expect from it
	I7	When somebody asks me for directions, I give them the first route that comes to mind
	I8	I am impatient when I do not find the best route quickly
	I9	I dislike it when a traffic sign or a sign combination is unclear
	I10	I find that establishing consistent travel habits is comfortable
	I11	I dislike it when an intersection offers multiple lanes for the direction I need
	I12	I dislike unpredictable traffic situations
MDSI	I13	I pay close attention to road signs
	I14	I drive over the speed limit in the city
	I15	In a traffic jam, I think about ways to get through the traffic faster
	I16	When the car in front of me doesn't move at a green light, I honk
	I17	It frustrates me that some road rules are completely unnecessary
	I18	I tend to drive cautiously
	I19	I get impatient during rush hours
	I20	I feel nervous while driving
	I21	I exceed the speed limit by 10-15% on highways in good weather and low traffic
	I22	I am ready to react to unexpected maneuvers by other drivers
	I23	I do not fully stop the car at a STOP sign
	I24	I base my behavior on the motto "better safe than sorry"
	I25	I feel I have control over driving (R)
	I26	Lost in thoughts or distracted, I fail to notice a change in traffic until the last second
	I27	I feel that some road rules are completely unnecessary
	I28	Driving makes me feel frustrated
	I29	When the lane next to me starts to move, I switch to it immediately
	I30	I nearly hit something due to misjudging my gap in a parking lot
	I31	I leave the car parked for short periods (10–15 min) in unauthorized places
	I32	I feel comfortable while driving (R)
	I33	I forget that my lights are on full beam until flashed by another motorist
	I34	I misjudge the speed of an oncoming vehicle when passing

The sample focused on Hungarians with expertise about transport and traffic for two reasons: (i) Hungarians are road users exposed to the highest possible number of traffic signs per pole according to the regulations by their road authorities; (ii) expertise about transport and traffic allows gauging the right temperature of the perception of safety, the evaluation of possible improvements and the interpretation of the signs. The questionnaire was distributed via social media and professional societies in Hungary, as well as a smaller number in Denmark, and a raffle was associated with the questionnaire to attract a large number of participants.

2.2 Survey data analysis

The analysis focused initially on the characteristics of the sample from a socio-economic perspective. Then, factor analysis was performed on the items of the two scales after checking the reliability of the sample by calculating the Cronbach's Alpha, the suitability to factor analysis of the sample by calculating the Kaiser-Meyer-Olkin (KMO) at the general and the item level. Principal Axis Factoring with and without rotation was performed on the factors and then factor scores were computed in order to have standardised scores of each participant on each factor.

As for the answers to the questions in the 12 locations, the following indicators were computed:

- number of legal manoeuvres correctly identified for the first (KN1) and the second (KN2) set of locations;
- perception of the number of conflicts as an average for the first 6 (NC1) and the second 6 (NC2) locations;
- perception of safety improvement as an average for the first 6 (SI1) and the second 6 (SI2) locations;
- perception of comfort level as an average for the first 6 (CL1) and the second 6 (CL2) locations;
- measure of helpfulness of traffic signs for the second 6 locations, average over all the signs (SH), only the obligatory ones (SHO), and only the prohibitory ones (SHP).

Standard scores were calculated for each participant for each factor after calculating averages and standard deviations of the indicators over the sample. Lastly, correlations were calculated between the factor scores and the performance standard scores to evaluate the relation between driving styles and need for closure on the one hand, and

the indicators on the other, while analyses of variance were computed to examine the relation between socio-economic characteristics and the indicators of the participants.

3. Results

3.1 Sample characteristics

A sample of 753 participants completed the questionnaire in every part and provided the basis for the analysis. The majority of the sample was composed by male participants (65%) and the age was mainly under 30 years old (59%) although a significant percentage was between 31 and 50 years old (32%). Most participants identified themselves as non-professional car drivers (76%), while some declared to be mainly car passengers (9%) or cyclists and pedestrians (11%). While most participants had engineering expertise, it is interesting to note that they had field experience with traffic signs (30%), traffic control (16%), urban planning (15%), strategic planning (11%), and road safety audits (9%). Clearly, the target audience was reached with the questionnaire and it should be noted that the young age is most likely related to the generation of professionals being young in developing countries.

3.2 Factor analysis

Exploratory factor analysis was performed by analysing the answers to the items presented in table 1. While latent factors have been uncovered in the literature, exploratory analysis was preferred to allow for possible latent constructs emerging from the administration of the two scales at the same time.

Initially, the reliability of the survey was established by observing a very good internal consistency of the answers at the overall level (Chronbach's Alpha = 0.75). Then, the suitability of the survey to factor analysis was verified via the calculation of very good values of sampling adequacy at the general level (KMO = 0.846) and the item level (KMO varying between 0.726 and 0.908), the passing of the Bartlett's test of sphericity (chi-square = 6494.6, df = 561, p = 0.000), and the verification that the Spearman correlation matrix contained elements between 0.3 and 0.7 and had a determinant over 10^{-5} . Principal Axis Factoring with Varimax rotation provided a solution with 8 factors that were named according to the loading of the items (the items loading highly on each factor are provided in parenthesis):

- anxiety (I20, I22, I25, I28, I30, I32);
- aversion to ambiguity (I2, I9, I12);
- habit (I1, I4, I5, I6, I10, I11);
- tendency to speed (I14, I21, I23);
- distractedness (I26, I29, I31, I33, I34);
- impatience (I8, I15, I16, I17, I19);
- tendency to follow rules (I3, I13, I18, I24);
- tendency to consider some rules unnecessary (I17, I27).

3.3 Differences across socio-demographic characteristics

Gender was highly related to differences in the computed indicators, as the means in 8 of the 9 calculated measures were significantly different between men and women (the only exception being the number of legal manoeuvres correctly identified for the second 6 locations). Men individuated correctly a higher number of legal manoeuvres for the first locations focusing on ambiguity ($t = -3.587$, $p = 0.000$), while women had a higher perception of all the locations being not safe as they estimated a higher number of conflicts in both the first 6 ($t = 5.903$, $p = 0.000$), and the second 6 locations ($t = 6.408$, $p = 0.000$) section. The higher perception of unsafe locations was mirrored by women feeling a greater improvement than males after removing the ambiguity in the first 6 ($t = 5.981$, $p = 0.000$; $t = 3.465$, $p = 0.000$; equal variance not assumed according to the Levene's test) and the second 6 locations ($t = 7.083$, $p = 0.000$; $t = 5.739$, $p = 0.000$; equal variance not assumed according to the Levene's test).

Age was also associated with differences in the computed indicators. Analysis of variance revealed that younger survey participants (less than 30 years old) felt that a lesser improvement in safety after the information was provided for the first 6 locations (mean diff. = -0.309, $p = 0.048$) as well as for the second 6 locations (mean diff. = -0.419,

$p=0.004$). A similar trend is observed also when comparing the younger participants to the ones over 50 years old in terms of perceiving a smaller improvement in the comfort level when adding the information (mean diff. = -0.440, $p=0.002$). The older participants in the survey (over 50 years old) perceived in turn a greater improvement in safety with the removal of the ambiguity with respect to both the 31-50 years old (mean diff. = 0.327, $p = 0.045$) and the younger than 30 years old (mean diff. = 0.419, $p=0.004$). They also found the obligatory signs to be more helpful when compared to both the 31-50 years old (mean diff. = 0.202, $p = 0.029$) and the younger than 30 years old (mean diff. = 0.425, $p=0.003$). While those aged 17-30 identified a higher number of correct manoeuvres in the second set of locations than those 51 or older (mean diff. = 0.346, $p = 0.022$).

The type of road users was also relevant to obtaining differences in the calculated indicators. Professional car drivers estimated a lower number of conflicts than car passengers in the first 6 (mean diff. = -0.068, $p = 0.047$) as well as in the second 6 locations (mean diff. = -1.023, $p = 0.000$), and they perceived higher safety also than general car drivers (mean diff. = -0.759, $p = 0.005$). Intuitively, vulnerable road users such as cyclists and pedestrians perceived the level of safety being lower with respect in particular to professional car drivers (mean diff. = 0.910, $p = 0.002$). In general, traffic signs were considered to be more helpful by car passengers than car drivers (mean diff. = 0.362, $p = 0.034$), in particular when it came to prohibitory signs (mean diff. = 0.517, $p = 0.000$).

Interestingly, driving frequency was not related to any of the computed indicators, with the exception of prohibitory signs. Specifically, drivers who used the car only monthly found prohibitory signs to be more helpful than drivers who used the car daily (mean diff. = 0.452, $p=0.002$).

3.4 Differences across driver style and need for closure

The correlation analysis (Table 2) between the 8 factors and the computed indicators provided information about the relation between driving style, need for closure and indicators calculated for each participant.

Table 2. Correlation between driving styles and the performance indicators

Factors	KN1	NC1	SI1	CL1	KN2	NC2	SI2	CL2	SH	SHO	SHP
Anxiety	-0.090	0.103	0.003	-0.057	0.016	0.093	-0.017	-0.059	0.025	-0.026	0.056
Aversion to ambiguity	-0.012	0.121	0.104	0.105	0.015	0.111	0.118	0.116	0.042	0.057	0.075
Habit	0.053	-0.086	-0.053	-0.016	0.055	-0.207	-0.141	-0.152	-0.226	-0.167	-0.181
Tendency to speed	0.007	-0.009	-0.127	-0.127	-0.152	0.022	-0.026	-0.021	0.012	-0.019	0.022
Distractedness	-0.050	0.150	0.151	0.122	-0.054	0.196	0.267	0.258	0.268	0.230	0.244
Impatience	-0.061	0.035	-0.012	-0.019	-0.024	0.070	0.007	0.013	0.053	0.034	0.048
Tendency to follow rules	-0.021	0.160	0.175	0.207	-0.006	0.123	0.192	0.200	0.189	0.158	0.185
Tendency to consider some rules unnecessary	0.006	-0.043	-0.057	-0.035	-0.047	0.004	-0.103	-0.101	-0.134	-0.105	-0.131

Note: *italic value* significant at the 0.05 level, **italic and bold value** significant at the 0.01 level

The analysis of the correlation matrix uncovers some significant correlation. Road users who were on the higher end of the anxiety factor scores were also higher on the estimation of the number of legal manoeuvres in the first 6 locations, but were lower on the perception of safety as they considered higher numbers of conflicts across all the 12 locations. Respondents who scored higher on the aversion to ambiguity were lower on the perception of safety for all the 12 locations, but they were also higher when considering the improvements associated with the provision of information and consequently they were higher on the comfort level with the second configuration of the locations. Participants who recorded higher values on the habit factor scores recorded lower values on the number of conflicts in all 12 locations and in particular in the second 6 ones, but recorded higher values when considering the improvements with the provision of traffic sign in both the comfort level and the perception of safety, although they seemed related to the provision of traffic signs in the second 6 locations not being particularly helpful.

Road users with a more marked tendency to speed provided a lower number of correctly individuated legal manoeuvres in the second 6 locations, while in the ambiguity cases of the first 6 locations they seemed not to perceive improvements in safety and not to increase their comfort level after the information being provided in the second configurations. Respondents who were on the higher end of the distractedness factor scores were on the lower end in

the perception of safety across all the 12 locations, but scored higher when considering the perception of the improvements following the addition of traffic signs and when considering their comfort level with the updated configuration of the locations.

Road users who scored higher on the tendency to follow rules recorded higher values in the estimation of conflicts in all 12 locations, and then also in the evaluation of the improvements in the safety and comfort level after the traffic signs were added. They also scored higher in the evaluation of the helpfulness of the traffic sign in the second 6 locations. Respondents who were higher on the factor expressing the tendency to consider some rules as unnecessary were lower on the evaluation of the helpfulness of traffic signs in the second 6 locations, and they were also lower on the estimation of the improvements in terms of safety and comfort level after the traffic signs were added across the 12 locations. The only factor without a significant correlation with any of the indicators was the impatience factor.

4. Conclusions

When considering the three hypotheses, the survey design and the data analysis provide insight into their correctness. Having prepared the questionnaire and collected the information about observable and latent characteristics of the survey respondents, a couple of considerations apply.

Firstly, road users are indeed heterogeneous in their perception and processing of information. The distribution of the number of legal manoeuvres correctly identified as legal across the sample suggests that differences exist, and the statistical analysis shows that gender, age and experience are related to these differences. Secondly, the amount of information plays indeed a role in the perception of safety by road users. In fact, the socio-economic characteristics are also associated with the perception of the improvements after providing information by adding traffic signs, as differences exist in the way road users perceive as better a situation with more information. Thirdly, indeed a different amount of information for each road user is sufficient not to feel uncertain regarding manoeuvres being legal at a certain traffic location. This is a consequence of the previous two hypotheses being verified, as not always the respondents who scored high on the number of legal manoeuvres correctly identified were also high on the perception of safety.

When looking at the detailed answers for each configuration and each location, it seems that there exists a safe minimum information level for the different driving styles and need for closure, as the correlation patterns suggest. Further research with a modelling approach might provide further insight into the relation between driving style, need for closure, socio-economic characteristics on the one hand, and the legality of manoeuvres, the perception of safety and the evaluation of improvements with the provision of traffic signs on the other.

Acknowledgements

The authors express their gratitude for helping spread the questionnaire to Dr. János Tóth, Head of the Transport Processes and Transport Economics Department at the Budapest University of Technology and Economics, Dr. Ádám Török and Tibor Sipos from the Transport Science Institute, and the editors of SzeretlekMagyarország.hu. The study is partially funded by the SUSTAIN project, supported by the Danish Innovation Fund.

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