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Dysfunctional Impulsiveness and Violations of Social Norms as Important Variables of Comprehensibility of Non-Standard and Non-Typical Road Sings by Polish Drivers

ABSTRACT

Road safety is one of the most important challenges facing modern civilization. In recent decades, loss of life as a result of road traffic has been one of the leading causes of death worldwide. This makes the social mission of integrating the main elements of the road traffic system in such a way as to make it safe a modern necessity. Interdisciplinary research on improving road safety should therefore cover not only humans (drivers) but also other road users, the road and its surroundings, and increasingly sophisticated intelligent vehicles. In this article, we present the results of research on drivers' understanding of non-standard road and environmental signs. Non-standard signs are now widely used around the world to improve traffic organization and increase safety. However, there is still little research on the extent to which these signs actually improve traffic flow, thereby increasing safety, and whether they are comprehensible to drivers. Research has shown that unusual signage is more comprehensible when it contains only symbolic elements rather than a combination of symbolic and

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textual elements. Unlike symbolic and textual signs, symbolic signs are also better understood by drivers with personality traits associated with dysfunctional impulsivity and a tendency to break social norms.

KEYWORDS: comprehensibility traffic signs; impulsivity; non-standard signs; tendency to break social norms

INTRODUCTION

The evolution of mobility, particularly in the field of automobiles, stands as the testament to rapid technological and civilizational progress. Mobility plays a key role in determining the quality of life in modern society and it is interconnected with multiple aspects of social functioning. The road traffic system itself is a classic example of how important it is for different components to be interconnected and integrated. Even minor irregularities in any of its components – whether related to legal regulations, the vehicle, the road, the human factors or the environment., can result in various negative consequences. These consequences claim hundreds of thousands of lives and leave millions injured each year. As a result, this makes transport mobility one of the leading causes of mortality worldwide. Both the number of road accidents and their severity are unprecedentedly higher in developing countries compared to developed ones. Poorly developed road infrastructure and the lack of appropriate legal regulations seem to be the main reasons. However, the causes of road accidents are investigated in the whole road traffic system, i.e. safe car design, and the education of drivers regarding adequate behavior on roads, as well as the construction of safe roads. In the latter case, the issue of designing road signs is of particular importance. Road signs should inform drivers effectively about the potential road hazards while requiring minimal engagement of the drivers' cognitive resources and allowing their effective comprehensibility at the

same time.. Human cognitive resources are limited, yet drivers are faced with an overwhelming number of stimuli on the road. Consequently, the information presented to drivers should be restricted to what is truly essential and critical for road safety. Studies indicate that when the number of road signs failing to meet established quality standards increases, the rate of traffic accidents rises accordingly (Ferko et al., 2019, Xu et al., 2018; Saric et al., 2018). It is equally important that road signs provide a clear message to drivers and thus are fully comprehended by road users. The issue of traffic sign comprehensibility has been examined in recent studies on driver behavior in both developing and developed countries, particularly those with highly saturated automative markets. Differences in driving patterns across multiple countries emphasize that drivers' knowledge of traffic signs and the comprehensibility of their meaning is an important safety concern (Shinar et al., 2003; Jamson & Mrozek, 2016). Researchers emphasize that from the perspective of comprehension three key elements of signs are important a) familiarity, b) compliance with current standards and c) the stimulus-concept compatibility (Ben-Bassat & Shinar, 2006; Jamson & Mrozek., 2016; Liu & Ho, 2012). Therefore, examining the comprehensibility of traffic signs continues to be a matter of relevance and importance.

Over the last two decades, general comprehensibility of traffic signs has been extensively analyzed in the Middle East in Bahrain, Kuwait, Oman, Qatar, United Arab Emirates, Jordan, Turkey (Kirmizioglu & Tuydes-Yaman, 2012; Al-Madani & Al-Janahi 2002a; 2002b; Taamneh & Alkheder 2018), Nigeria (Makinde & Opeyemi, 2012, Makinde & Oluwasegunfunm, 2014), Thailand (Choocharukul & Sriroongvikra, 2017), i.e. countries where automotive ratio is not the highest. The analysis revealed that the overall level of traffic signs comprehensibility in different groups of drivers is within the range of 47% (Al-Madani & Al-Janahi 2002a) to 70% (Kirmizioglu & Tuydes-Yaman, 2012) – indicating not a significant level of their comprehensibility. Paradoxically,

the issue of understanding traffic signs is not only limited to developing countries – the issue also occurs in highly motorized nations. Across the years, there has been a growing intensity of migration within European countries, which in conjunction with considerable diversity of traffic signs has lead to confusion among drivers. Studies show that the average correct comprehension rate of traffic signs is only about 60% (Shinar et al., 2003, Jamson & Mrozek, 2016). Problems with signs comprehensibility – especially with traffic control devices- are particularly evident among foreign drivers (Dissanayake & Lu, 2002). Domestic drivers demonstrated a higher level of understanding of traffic signs, traffic markings and signals. An exception was discovered by Al-Madani and Al-Janahi (2002b) who showed that drivers from Europe and the US showed a much better comprehensibility than Asian and Arab drivers.

A considerable amount of research has investigated how socio-demographic factors influence traffic sign comprehension. Regarding gender variable, men tend to demonstrate a higher level of comprehension than women (Al-Madani & Al-Janahi, 2002a; 2002b). This pattern was also observed among drivers in several European countries such as Great Britain, Germany, and Poland (Jamson & Mrozek, 2016). The relationship between age and comprehension has shown to be more complex and less consistent. Several studies found that the level of traffic signs comprehension decreases with age (Ben-Bassat & Shinar, 2015; Shinar et al., 2003; Dewar et al., 2001), while the others reported the opposite (Liu and Ho, 2012; Al-Madani & Al-Janahi, 2002b). Another two discovered that there is no significant relationship between age and comprehension (Al-Madani & Al-Janahi 2002a; Taamneh & Alkheder, 2018). On the other hand, experience and education have shown to positively impact traffic sign comprehension (Al-Madani & Al-Janahi, 2002a, 2002b; Taamneh & Alkheder, 2018; Ng & Chan, 2008). In contrast, factors such as marital status, accident history, nationality (Al-Madani & Al-Janahi, 2002a), or duration

of active driving experience (in years) and the frequency of car using (Ng & Chan, 2008) were less frequently studied and these variables have little impact on drivers' comprehension of traffic signs.

A separate line of research has analyzed traffic signs themselves - their functions, messages and content. In the search for factors, which regulate the comprehensibility of traffic signs, their contextual presentation has been investigated (Ben-Bassat & Shinar, 2015). The mode of the traffic sign presentation (with or without contextual background) did not affect the traffic signs comprehensibility, however, the presence of context increases the time required for drivers to comprehend their meaning.

Several other studies have focused on exploring the differences in the traffic signs comprehensibility depending on their content – especially whether the sign contained only a graphic symbol or also included verbal information (Liu & Ho, 2012; Shinar et al. 2003; Dewar et al. 2001; Shinar & Vogelzang, 2013). Research revealed that the highest level of comprehensibility was found for symbolic traffic signs, particularly when the symbol in the traffic sign was consistent with its semantic meaning. This proved to be the most significant predictor of correct traffic behavior (Liu & Ho, 2012), especially among young and middle-aged drivers (Dewar et al., 2001).

A different study conducted by Shinar and Vogelzang (2013) examined the overall comprehensibility and reaction time of traffic signs when shown in various conditions. Some of the conditions included displaying solely the symbols, text or both text and symbols. Their findings showed that display conditions significantly affect comprehensibility and reaction time of drivers. Adding text to a symbolic traffic sign improved the level of comprehensibility and reduced the time needed to comprehend its meaning (Shinar & Vogelzang, 2013).

Shinar et al. (2003) assessed the overall level of comprehensibility of symbolic highway signs used in different countries. They

compared the levels of comprehensibility of symbolic traffic signs in four countries with moderate or high levels of motorization in Canada, Finland, Israel and Poland. The results show significant differences in sign comprehensibility and among different group of drivers. Signs were best understood when they were coherent with the general ergonomic design principles - especially when it came to spatial and conceptual compatibility, physical representation, and standardization. More recent research carried out in three European countries has concluded that the key to improving comprehensibility of traffic signs lies in the overall standardization – particularly with regards to color, shape, and certain physical and special characteristics (Jamson & Mrozek, 2016). During a field experiment conducted at night, traffic sign legibility was compared under static and dynamic conditions. It was revealed that drivers require better luminance, in order to recognize text on signs while driving compared to static position (parking or at a stop) (Schnell et al., 2024). Other studies, which used driving simulators demonstrated that enhancing the nighttime visibility or roads signs and road markings positively affect drivers' cognitive load without leading to increased driving speed (Fiolić et al., 2023). Similar findings have been found in other studies, where the conclusion is that road markings and traffic sign quality are crucial for ensuring safety during nighttime driving (Babić et al., 2020a).

Undoubtedly, an interesting perspective on traffic signs comprehensibility is the analysis of driver's dispositional factors, particularly their impulsiveness. Impulsive driving consists of the tendency to behave immediately to satisfy one's own goals in traffic, and often that leads to disregarding needs of other road users and traffic safety. Impulsiveness involves rapid, unplanned reactions to internal or external stimuli and may lead to dangerous behaviors, such as ignoring important warning signals or displaying aggression (Dahlen &White, 2006; Heinz et al., 2015; Panayiotou, 2015; Bıçaksız & Özkan, 2016; Le Bas et al., 2015;

Starkey & Isler, 2016; Dorantes-Argandar et al., 2016). Drivers with impulsive personality traits may also select information from traffic signs and even ignore them completely. In this context, dysfunctional impulsiveness, identified by rapid, but inaccurate or chaotic processing of environmental stimuli (Dickman, 1990; 2000) may be of particular importance. Taking into consideration the effects of dysfunctional impulsiveness on driver behavior, one can assume that this trait can significantly affect not only the reception of stimuli such as non-standard and non-typical signs, but also the general level of comprehensibility.

Another factor, which can impact the comprehensibility of traffic signs is the attitude towards social norms. Numerous studies on drivers behavior have shown that the tendency to violate social norms is associated with various risky behaviors in traffic such as: drunk-driving (Moan & Rise, 2011; Vereeck & Vrolix, 2007; Eisenberg, 2003), dangerous driving behaviors (Nordfjærn et al., 2015; Rimal & Real, 2005), speeding (Cestac et al., 2011; Conner et al., 2003; Elliott et al., 2013; Scott-Parker et al., 2009; Simons-Morton et al., 2012). In addition to that, the tendency to disregard social norms has also shown to regulate peer communication in relation to the normative social influence on risk-related behavior (Southwell & Yzer, 2007; Geber et al., 2019). The tendency to ignore social norms may also lead to disregarding to monitor traffic signs, which could result in reduced level of comprehension of these signs.

Traffic safety is not only dependent on appropriate knowledge and comprehension of commonly-used traffic signs, but also on the understanding unusual and non-standard markings, which are sometimes designed for a slim group of driver. Non standards and non-typical signs are mainly introduced, in order to improve communication in traffic, especially in situations, where information cannot be represented using a single, conventional sign. Research has shown that improving signage by introducing such signs can lead to decrease in traffic violations and increase in

road safety. The improvements studied in the mentioned research consisted of marking for lateral position of the vehicle (Davidse et al. 2004; Park et al., 2012) road curve signs and intersections (Awan et al., 2019; Calvi, 2018; Montella et al., 2015; Coutton-Jean et al., 2009; Charlton, 2007), additional types of road markings (Daniels et al., 2009; Ding et al., 2014, 2016; Charlton et al., 2018) wider edge lines (Fager, 2024) speed reduction markings (Babić & Brijs, 2021) self-luminous road markings (Shi et al, 2025), and horizontal curves (Pirdavani et al., 2025). Therefore, in recent years, there has been a growing number of research, which studies the impact of new, additional non-standard signs on traffic safety (Babić et al., 2020a, 2020b).

Research aim

Proper perception of traffic environment is one of the significant prerequisites of efficient and safe driving. The use of simple and standard traffic infrastructure solutions promotes this process. However, there are cases, where unusual traffic solutions must be used or traffic conditions deviate from those to which road users are accustomed, e.g. in roadworks zones or during unexpected weather phenomena, etc. In such cases, traffic marking becomes particularly important, as it should help drivers make the right decision in a timely manner.

Due to the variety of potential road designs and possible traffic situations sometimes requires the use of non-standard traffic signs. This applies to cases where the information portrayed by standard markings is insufficient for drivers to properly understand the traffic situation or fail to behave accordingly. Therefore, the needed efforts are made to introduce non-standard signs with unusual form or supplementary information to capture the attention of drivers and provide enough information, so they can make the correct and safe decision. On the other hand, several studies have shown that an excessive number of traffic signs within a limited roadside space, regardless of whether they are symbolic or textual

signs, may lead to reduced reception and processing by drivers. In other words, they are poorly recognized and comprehended. Large number of traffic signs impact's the drivers' perceptual and cognitive systems, and drivers may feel overwhelmed by having to simultaneously perform tasks such as: monitoring the road, checking vehicle displays, identifying potential hazards, and interpreting traffic signs. It is known that dispersed distribution of attention can lead to critical driving events (Wierwille, 1993). Moreover, when numerous signs are placed along within limited road space, drivers can choose to ignore some of them and classify them as distractors and insignificant for their driving goals. This process can be furtherly worsened due to drivers' limited perceptual and cognitive resources available, as they decline significantly due to age, fatigue, and drowsiness (Kaplan et al., 2007; Howard et al., 2014; Williamson et al., 2014). Therefore, doubts may arise whether introducing unusual signs or supplementing existing signs with additional elements will be effective in evoking the desired driver responses. They key factor in evoking the right appropriate driver behavior is comprehensibility of the signs' contents, particularly when their purpose is to enhance spatial awareness and the correct assessment of traffic situation..

The mentioned conditions lead to the creation of the first hypothesis by the authors (Hypothesis 1) which assumes that it is possible to use non-standard signs, but their comprehensibility and potential impact on traffic participants varies depending on the nature of their content. It was hypothesized that signs with both symbol and text will be more understandable than solely symbolic or solely textual ones. This reasoning is based on the belief that the symbolic elements of already known signs do not require considerable attention, while only the new, additional elements. However, the question arises as to whether such a sign will be communicative to the driver, and whether all the information it contains (both text and symbolic) will be processed. This is especially true for signs encountered occasionally in the traffic.

In addition, the study aimed to check whether higher traffic signs comprehensibility is related to personal characteristics of drivers, such as dysfunctional impulsiveness, as well as social attitudes related to ignoring or violating social norms. The second hypothesis (Hypothesis 2) assumed that both personality traits, namely dysfunctional impulsiveness together with driver's tendency to break social norms would be negatively linked with the level of traffic sign comprehensibility. The expectation was that drivers with a higher tendency to break social norms and dysfunctional impulsiveness would demonstrate worse comprehensibility of non-standard traffic signs.

RESEARCH METHODOLOGY

Materials and tools

Three categories of traffic signs were used for the study that differed from typical ones described in Polish traffic law: a) regulators signs b) warning signs and c) guidance signs. All three groups of tested signs represented completely new types of traffic information for Polish roads. The first two included symbolic and symbolic-text signs. The third category included information intended solely for emergency and technical services (police, fire brigade, ambulance, technical services of the highway), referred to as non-typical (guidance) symbolic regulatory signs (Figure 1).

According to the American National Standard Institute (ANSI Z535.3), an 85% correct response criterion was adopted for assessing traffic signs comprehensibility and familiarity (Wolff & Wogalter, 1998). However, the tested signs were completely unknown to Polish drivers, as they were not included in driver education, nor were they present in any social awareness campaigns. Therefore the study adopted soft comprehensibility criteria and level of 60-85% was classified as average. Lowering the threshold of comprehensibility to 60% was justified by the fact

Figure 1. Studied regulatory and warning signs

	1	2	3	4	5
Symbolic regulatory signs (SRS)					
Symbolic and text regulatory signs (STRS)		 			
Symbolic warning signs (SWS)					
Symbolic and text warning signs (STWS)					
Non-typical (guidance) signs (NTS)					

that the signs used for the study were already implemented in practice and thus an "educational effect" was expected to occur, by potentially increasing the level of comprehensibility that was initially recorded in the survey. This was an important criterion, which impacted the decision to maintain the signs on the road for further study. Sign comprehensibility below 60% was classified as poor and in such cases, additional consideration was conducted to determine, whether the sign should remain on the road. These analyses were beyond the scope of this study.

In addition to the graphic material (traffic signs), two-part questionnaire was also conducted. Part one collected the respondents'

descriptive data, such as: age, gender, driving license category, driving experience, and education. The second part investigated traffic signs familiarity and comprehensibility. Traffic signs familiarity was measured by asking "Have you ever encountered such a sign on the road while driving?" The results were measured on a five-point scale. The subjects could choose among five possible answers: 1. *No, never*. 2. *I think so, but I don't remember where.* 3. *Yes, several times on different roads.* 4. *Yes, on the highway*. 5. *Yes, abroad*.

Comprehensibility was verified on the basis of a multiple choice format. Per each sign, participants were presented with a 5 to 9 answers, where only one accurately described the shown sign. Other options presented fragmentary meaning of the sign, covering only some of its elements. To eliminate accidental associations of comprehensibility, each letter also contained one meaning that was completely incompatible with the sign message.

In addition, two psychological tests were used in the study to measure impulsivity: the Dickman Impulsivity Inventory (11 items for functional impulsivity; Dickman, 1990) and the Attitude Scale Toward Social Norms (12 items for dysfunctional impulsivity: Wontorczyk, 2011). The internal consistency of the scale, as estimated by Cronbach's alpha extended from 0.81 to 0.87. Participants were meant to answer using a four point scale, where: 0 = *totally false*, 1 = *partly false*, 2 = *partly true*, and 3 = *totally true.* Based on the Attitude scale toward social norm (Wontorczyk, 2011) consisted of four items rated on a five-point scale, where: 1 = *strongly disagree* and 5 = *strongly agree*. The internal reliability of this scale using Cronbach's alpha was 0.83.

Research procedure

After obtaining informed consent from the participants they were showed a traffic sign and asked to examine it and indicate their level of familiarity using a five-point scale. Next, the comprehensibility of the given sign was examined by asking the subjects to read a list of meanings and select the one that best describes the

reviewed sign. There was no time limit.. Participants were allowed to return to previously answered questions, if they considered that they had given the wrong answer. Next, participants were asked to complete the Dickman Impulsivity Inventory and the Attitude Scale Toward Social Norms.

Subjects

The study was conducted in south-eastern Poland, i.e. the following provinces: Lubelskie, Podkarpackie, Małopolskie and Świętokrzyskie. The total number of participants was 358 (203 men and 155 women), between the ages of 18 and 65. Among them, 180 were amateur drivers, 41 were truck drivers, 18 were. bus and coach drivers, as well as 19 taxi drivers. Participants had various driving experience, for example 115 drivers had driven more than 10,000 kilometers per year, 91 drivers between 11,000 and 20,000 kilometers and 54 drivers between 21,000 and 40,000 kilometers, and 98 drivers had driven more than 40,000 kilometers per year

RESULTS

The analysis first explored the overall comprehensibility of the three groups of signs that were presented in the study; next the team assessed how compressibility related to the chosen independent variables in order to distinguish potential moderators.

The level of comprehensibility of symbolic and symbolic text regulatory signs

According to the adopted sign comprehensibility criteria, correct response rate above 86% indicates a high comprehensibility for a group of signs and for the individual signs within that group. Signs, which obtained scores in the range of 50-85% were classified as average, while the signs which scored below 50% were

considered as very poorly comprehended. the overall level of comprehensibility of the presented symbolic regulatory signs was average and equal to 50.4%.The greatest variation in comprehensibility was found in the group of symbolic signs, which ranged from the upper limit of average to very poor comprehensibility. And so the average comprehensibility rate was observed in the case of three signs RS1, RS2 and RS3. It was: RS1 = 74%, RS2 = 72% and RS3 = 68% respectively. In turn, the other two signs from this group obtained a very low level of comprehensibility and it was RS4 sign = 31% and only 7% for RS5 sign. The range of comprehensibility for this group of signs was therefore very high because it was as much as 68% between the best and the least comprehended sign.

The symbolic-text signs were understood less and the general level of comprehension was equal to only29.5%. The results varied significantly across individual signs to: STR1 = 47%, STR2 = 41%, STR3 = 22%, STR4 = 16% and STR5 = 8% respectively. A vivid pattern was observed in this group, as comprehensibility tended to decrease as the number of verbal elements within the sign increased. E.g. STR1, a sign with the highest level of comprehensibility in this group consisted of only one symbolic and one verbal piece of information, while STR5 sign – with the lowest comprehensibility included three symbolic and three verbal pieces of information.

The level of comprehensibility of symbolic and symbolic text warning signs

Only four symbolic and symbolic-text warning signs were included in the study. Their overall level of comprehensibility was on average at 63%. It was also the highest comprehensibility of all five types of signs included in the study. The results were relatively consistent within this group: SWS1 = 73%, SWS2 = 68%, SWS3 = 57%, SWS4 = 54%. The difference between the best comprehended (SWS1) and the poorest comprehended sign

(SWS4) was 19 percentage points, which was also the smallest variation among all examined groups.

In the case of symbolic-text signs, their overall comprehensibility ratio was also very poor at 18.3% – the lowest result among all sign types. The comprehensibility ranged between the best (STWS3 = 32%) and the poorest comprehended (STWS4 = 8%) resulting in a 24-percentage point difference. The number of symbols on one display is worth noting for this group of signs. For example, STWS1, STWS2 included as many as three graphic symbols, while STWS3 (the best comprehended in this group) only one symbol. STWS4 sign was the exception. It included one symbol, but three words and it resulted with the lowest level of comprehensibility (only 8%).

Level of comprehensibility of non-typical signs

The role of non-typical signs as crucial guidance providers for drivers on highways also contributed to the analysis. Their level of comprehensibility among the studied group of drivers was very low and amounted to only 13%. However, it should be noted that the general comprehensibility of these signs among drivers was very good at 83%, approaching the threshold for high comprehensibility.

To compare the comprehensibility among different groups, the original interval data was changed into nominal, one, where 1 was assigned to a completely correct interpretation of the sign's meaning, and 0 was assigned to partially correct or incorrect answer. This change helped to determine the overall comprehensibility at a group level, as shown in Table 1. A one-way analysis of variance (ANOVA) confirmed that the differences between the mean obtained in individual groups of the analyzed traffic signs were statistically significant ($F[4.354] = 22.78$; $p = 0.001$), $\eta^2 = 0.07$.

Table 1. SPSS descriptive statistics of driver comprehensibility of traffic signs

Traffic signs (comprehensibility)	*N*	Min.	Max.	Mean	*SD*
Symbolic regulatory signs (SRS)	358	0.00	5.00	2.48	1.07
Symbolic and text regulatory signs (STRS)	358	0.00	5.00	1.46	1.12
Symbolic warning signs (SWS)	358	0.00	4.00	2.53	0.96
Symbolic and text warning signs (STWS)	358	0.00	4.00	0.78	0.72
Non typical signs (NTS)	358	0.00	2.00	0.26	0.55

The highest level of comprehensibility of traffic signs was found in the case of symbolic warning signs and symbolic regulatory signs. A much poorer comprehensibility was observed in the case of symbolic-text regulatory and warning signs. The lowest comprehensibility was observed for non-typical signs.

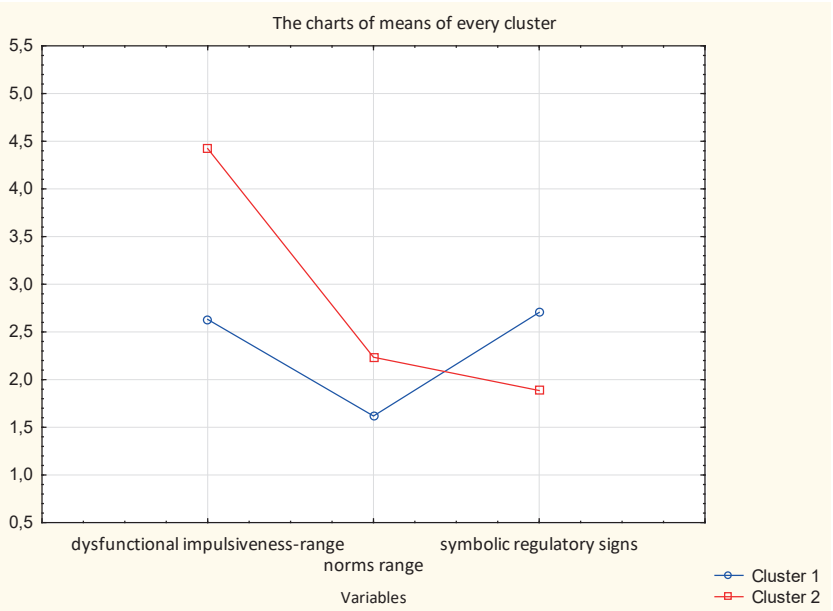
In order to verify, which group of signs significantly differed in terms of comprehensibility, Fisher's post hoc test was conducted. Statistically significant differences among pairs were obtained as following: SRS vs. STRS ($p = 0.03$), SRS vs. STWS ($p = 0.004$), SRS vs. NTS ($p = 0.001$), STRS vs. SWS ($p = 0.02$), STRS vs. STWS ($p = 0.006$), STRS vs. NTS ($p = 0.002$) vs. SWS vs. STRS ($p = 0.05$), SWS vs. STWS ($p = 0.007$), SWS vs. NTS ($p = 0.01$). These results show a clear pattern – symbolic signs, whether regulatory or warning were better understood by participants rather than symbolic-test signs, regardless of their type. Non-typical signs had the lowest comprehensibility, despite being important to drivers, fire services, and technical highway services.

Relations between impulsivity, attitudes towards social norms and the level of traffic signs comprehensibility

In the second stage of analysis, relationships between various dispositional features of drivers, e.g. dysfunctional impulsiveness and specific attitudes of the respondents towards social norms and traffic signs comprehensibility were investigated. Therefore, the variables were standardized and then subjected to cluster analy-

sis, in order to identify relationships between a given category of traffic signs, a variable personal dysfunctional impulsiveness and attitude towards social norms. The first analysis explored the relationship between comprehensibility of symbolic regulatory signs and the corresponding results are presented in Table 2. Two distinct driver profiles emerged through the analysis of the clusters formed by the three variables, where each proved to be statistically significant (Figure 2).

Figure 2. Graphic characteristics of clusters between the variables of dysfunctional impulsiveness, attitudes towards social norms and comprehensibility of symbolic regulatory signs



Profile I describes a group of drivers, who obtained high scores on the dysfunctional impulsiveness scale and presented a slightly above average acceptance for breaking social norms, as well as showed a poor comprehensibility of symbolic regulatory traffic

signs. Profile II contains opposite features, as this group of drivers obtained low results on the scale of dysfunctional impulsiveness, and attitudes towards social norms, while above average in terms of comprehensibility of symbolic regulatory traffic signs.

Table 2. Statistical measures of clusters between variables of dysfunctional impulsiveness, attitudes towards social norms and comprehensibility of symbolic regulatory signs

	Mean		*SD*		Statistical significance of differences between means	
	Cluster I	Cluster II	Cluster I	Cluster II	*F*	*p*
Dysfunctional impulsiveness	2.631	4.422	0.743	0.823	472.050	0.001
Social norms	1.618	2.234	0.6041	0.630	89.397	0.001
Symbolic regulatory signs	2.704	1.885	0.964	1.043	59.884	0.001

A similar pattern of relationships between comprehensibility and the variable of dysfunctional impulsiveness was observed for both symbolic-text regulatory signs and symbolic warning signs. In each of these cases, participants with higher scores on the dysfunctional impulsiveness scale and who tended to break social norms have demonstrated a lower level of traffic signs comprehensibility. The opposite can be observed for drivers, who scored lower on the dysfunctional impulsiveness scale and on violation of social norms (Figures 3 and 4). All of the previously mentioned results were statistically significant (Tables 3 and 4).

Table 3. Statistical measures of clusters between variables of dysfunctional impulsiveness, attitudes towards social norms and comprehensibility of symbolic-text regulatory signs

	Mean		SD		Statistical significance of differences between means	
	Cluster I	Cluster II	Cluster I	Cluster II	F	p
Dysfunctional impulsiveness	4.160	2.562	0.955	0.752	314.356	0.001
Social norms	2.149	1.573	0.636	0.605	78.054	0.001
Symbolic Text regulatory signs	1.044	2.092	0.861	1.142	97.630	0.001

Figure 3. Graphical characteristics of clusters between variables of dysfunctional impulsiveness, attitudes towards social norms and comprehensibility of symbolic-text regulatory signs

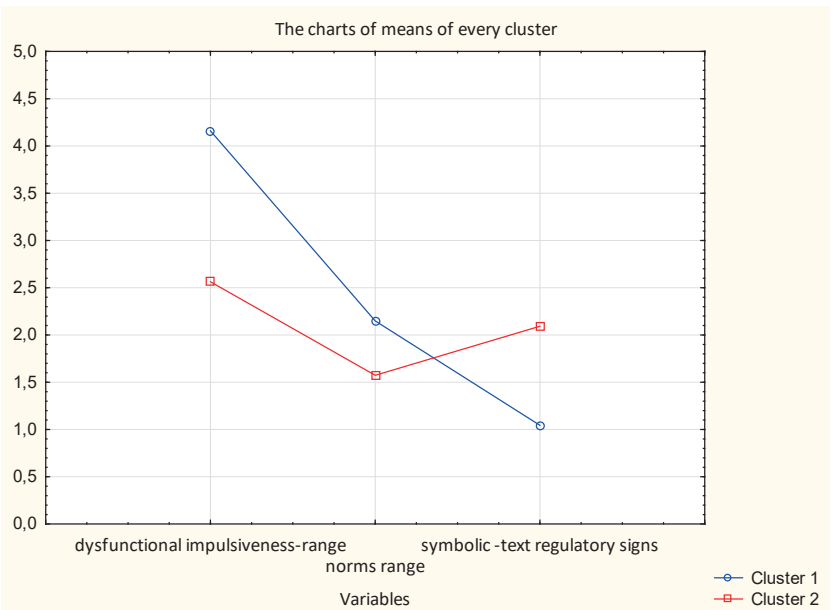
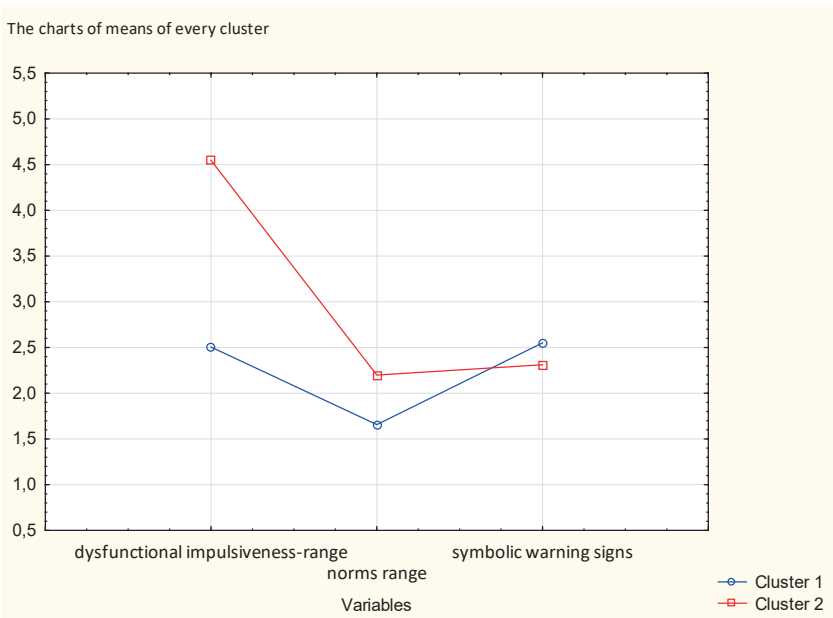


Table 4. Statistical measures of clusters between variables, dysfunctional impulsiveness, attitudes towards social norms and comprehensibility of symbolic warning signs

	Mean		*SD*		Statistical significance of differences between means	
	Cluster I	Cluster II	Cluster I	Cluster II	*F*	*p*
Dysfunctional impulsiveness	2.505	4.546	0.610	0.691	823.216	0.001
Social norms	1.656	2.198	0.607	0.657	61.264	0.001
Symbolic warning signs	2.550	2.312	0.904	1.022	5.135	0.054

Figure 4. Graphic characteristics of clusters between variables of dysfunctional impulsiveness, attitudes towards social norms and comprehensibility of symbolic warning signs

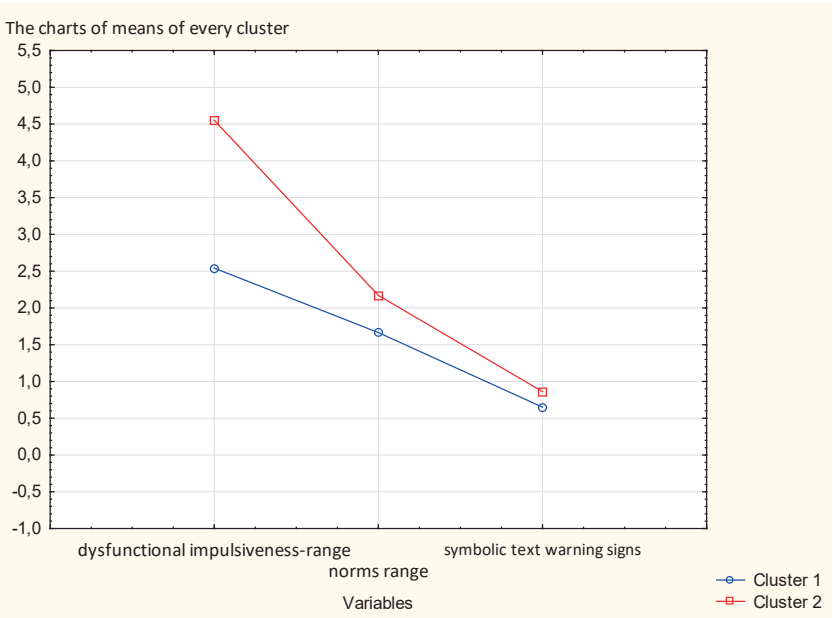


A completely different pattern was observed in the case of symbolic and text warning signs. Two clear clusters were identified across the analyzed variables which differed statistically significantly (Table 5). However, the cluster characteristics have emerged to be unexpected and presented extreme values on all variables. The drivers in cluster I, obtained higher results in all three variables selected – dysfunctional impulsiveness, tendency to violate social norms, and comprehensibility of symbolic-text warning signs compared to Cluster II (Fig. 5. This result shows two statistically significant tendencies, as drivers who scored higher on dysfunctional impulsiveness scale and have higher tendency to violate social norms simultaneously show a better comprehensibility of symbolic-text warning signs than drivers in Cluster II. Drivers, who belong in Cluster II have scored lower on impulsiveness and norm violations, and showed poorer comprehensibility of this sign category.

Table 5. Statistical measures of clusters between variables of dysfunctional impulsiveness, attitudes towards social norms and comprehensibility of symbolic-text warning signs

	Mean		*SD*		Statistical significance of differences between means	
	Cluster I	Cluster II	Cluster I	Cluster II	*F*	*p*
Dysfunctional impulsiveness	2.541	4.552	0.607	0.698	867.412	0.001
Social norms	1.665	2.171	0.609	0.678	56.195	0.001
Symbolic-text warning signs	0.651	0.861	0.690	0.76	7.619	0.05

Figure 5. Graphic characteristics of clusters between variables of dysfunctional impulsiveness, attitudes towards social norms and comprehensibility of symbolic-text warning signs.



However, it was not possible to derive statistically significant clusters for non-typical signs when comparing impulsiveness and the inclination to violate social norms with the comprehensibility of these signs.

Non-typical signs were omitted from further cluster due to two reasons. Firstly, they have shown to be poorly understood by the drivers, and second they are intended for a specific group of highways users, such are fire brigades, police, and technical road services. From a social perspective, they are not as relevant, when it comes to improving general road safety, as they merely present the location where a crossover to the opposite carriage-way is available.

DISCUSSION

Obtained research results clearly indicate that symbolic signs, unlike symbolic-text ones, were much better comprehended by drivers. Yet he level of comprehensibility of symbolic regulatory and warning signs was comparable. Hypothesis 1 was partially confirmed with the respect to non-standard traffic signs (warning and regulatory). As expected, the poorest level of comprehensibility was found for non-typical signs, which are only intended for certain traffic users (emergency and technical services, motorway maintenance, police, and other uniformed services). In general, our results were consistent with those obtained in other studies explored in introduction (Ben-Bassat & Shinar, 2015; Liu & Ho, 2012; Dewer et al., 2001; Shinar & Vogelzang, 2013). A certain exception is the study by Shinar and Vogelzang (2013), which found that the addition of text to a symbolic sign significantly improves its comprehensibility by drivers. In our studies, the opposite effect was observed, the symbolic-text signs were much less comprehensible than purely symbolic ones. There might be two reasons for this phenomenon. Our research used unusual non-standard signs, which drivers have not yet encountered in real road traffic, but which were intended to be introduced in the future as experimental signs by the administration of motorways in Poland. Secondly, some of the signs studied by us contained excessive number of messages (both verbal and symbolic), which may be difficult for drivers to integrate in a short time, which is due to limited capacity of human attention (Stern, 2003). Moreover, several signs included in the study (STRS3, STRS4, STRS5) contained unusual symbols, which were non-conventional and did not convey semantic context. Jamson and Mrozek (2016) drew attention to this issue and highlighted the need for sign standardization, in terms of color, shape, and their physical and spatial. It seems that an important issue is also taking into account the meaning of the symbol itself (shape, color, message model) in

the design process. Finally, the poorer level of drivers' comprehensibility of the analyzed symbolic and text signs, could also be affected by the fact that several different symbols were placed next to each other (STWS1, STWS2, STWS3). Even if these symbols are in line with the context, due to their number, it is difficult to fully integrate their meaning by human attention, as demonstrated in the results. Attention resources are more inclined to select easier or better comprehended messages, ignoring the more complex. This leads the drivers to the event, where they believe that they have processed the sign, even though they have not. This process is particularly observed in drivers, who demonstrate poorer cognitive resources (impulsivity dispositions) or in older adults. This is in line with current studies on central attention resources and cognitive reserve (Opdebeeck et al, 2018; Stern, 2003; Frankenmolen et al., 2018; Lojo-Seoane et al., 2014; 2018) and inferior brain reserve (Stern, 2003).

Interesting results were obtained in regarding the relationship between the level of signs comprehensibility with the dispositional features of drivers such as dysfunctional impulsiveness and a tendency to break social norms. In all three groups of analyzed signs, i.e. symbolic and symbolic-text regulatory ones, as well as symbolic warning, participants, who had higher results in terms of dysfunctional impulsiveness and showed a higher inclination to break social norms demonstrated poorer sign comprehensibility than from the opposite group. Thus, hypothesis II was fully confirmed. The results obtained in our study are consistent with previous studies on personality traits such as dysfunctional impulsiveness (Dickman, 1990; 2000). Impulsiveness, in particular dysfunctional, can not only be the cause of many dangerous behaviors in road traffic, as demonstrated in many studies (Heinz et al., 2015; Panayiotou, 2015; Bıçaksız & Özkan, 2016; Le Bas et al., 2015; Starkey & Isler, 2016; Dorantes-Argandar et al., 2016), but also foster a worse sign of comprehensibility. A similar tendency occurs in the case of inclination to violate social norms – these

drivers are more likely to drive under the influence of alcohol (Moan & Rise, 2011; Vereeck, & Vrolix, 2007), take risks (Nordfjærn et al., 2015), exceeding the speed limit (Cestac et al., 2011; Elliott et al., 2013; Simons-Morton et al., 2012). These individuals may also examine the content of traffic signs in a poorer manner, resulting in poorer comprehensibility. The obtained results are important because in the adult population, including drivers, there is a significant percentage of people with dispositional features of impulsiveness (Voon et al., 2010; Hammes et al., 2019; Whiteside & Lynam, 2001).

A certain exception in our research was the lack of relationship between the level of comprehensibility of symbolic-text warning signs and impulsiveness and a tendency to break social norms. This should be interpreted as the effect of an excess of both textual and symbolic information contained in these signs, which makes them very poorly comprehended or even incomprehensible to drivers. In the future, complex and ambiguous signs should be avoided in the design process.

CONCLUSIONS

The results in our study have a practical significance for improving road safety. They confirm that in order to enhance comprehensibility of signs, the content of road messages (including those placed on vertical and horizontal signs) should be minimized. Ideally, these signs should be symbolic representations, which can be easily identified by drivers based on their cognitive resources. Those types of symbols will not impede drivers' comprehension, even those, who have limited cognitive resources due to their dispositional traits, such as dysfunctional impulsiveness or inclination to violate social norms.

Limitations

Our study is cross-sectional and it is not without limitations. It should be noted, that over time participants could have been more frequently exposed to the presented signs, which could improve their comprehensibility. The effect of that could be furtherly measured, in order to control the potential learning effects. It is possible that drivers, who experienced discomfort when exposed to unfamiliar signs, could have searched for their meaning on their own. This could have contributed to an increase of their level of comprehension.

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