

Article

Traffic Sign Comprehension among Filipino Drivers and Nondrivers in Metro Manila

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Abstract: The current study examined 73 existing traffic signs in Metro Manila for their matching accuracy, matching time, and cognitive design features. A total of 60 Filipinos (30 drivers and 30 nondrivers) were voluntarily recruited to perform a matching-based comprehension test. In a matching-based comprehension test, the traffic sign is matched with the most appropriate referent name which shows a clear-cut distinction between correct and incorrect answers. To assess a sign's acceptability in a matching test, a level of at least 67% accuracy must be obtained in a comprehension test. For the matching accuracy, 27 of the 73 traffic signs did not comply with the 67% comprehension standard set by ISO 3864-1:2011. Drivers were found to have better matching accuracy for both regulatory and warning signs compared to nondrivers. Traffic signs displayed in symbols had the lowest matching accuracy and slowest matching time. When text was added to traffic signs displayed in symbols, matching accuracy and matching time improved significantly. However, signs displayed in text only obtained the highest matching accuracy and fastest matching time. The cognitive design features, which were the measurement of a sign's design, were also assessed through their familiarity, concreteness, complexity, and semantic distance. Cognitive design features were found to be positively correlated to matching accuracy for both regulatory and warning signs, but negatively correlated to matching time for warning signs. For signs displayed in symbols, cognitive design features were also found to be correlated to matching accuracy and matching time. To improve comprehension and road safety, semantic distance, concreteness, and familiarity are the key cognitive design features which must be considered by traffic sign designers. Also, the Department of Transportation (Philippines) could adopt the matching test of this study as a mandatory retraining requirement for the renewal of a driver's license. In addition, our matching-based comprehension test can also be applied and extended to evaluate existing traffic signs worldwide.

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1. Introduction

Traffic signs are the most frequent visual aids to communicate information about traffic laws and regulations, serving as reminder, direction, or warning [1]. According to Kraft et al. [2], a well-designed traffic sign is one that complies with a certain need, draws the road user's attention, and conveys a clear message in a clear and simple manner, giving the user enough time to respond correctly. Furthermore, the design of traffic signs should allow users to comprehend the correct information precisely and effectively to avoid conflicts or accidents in a changing traffic environment [3]. The ability to comprehend traffic signs is considered a major contributor to road safety, the failure of which could lead to more problematic issues [4].

Aside from road safety, pedestrian safety is also becoming a global concern because of the unprotected nature of pedestrians. Although roads are usually shared by both

pedestrians and vehicles, often less consideration is given to pedestrian safety compared to the ease of movement of vehicles and driver safety. Therefore, pedestrians are also susceptible to severe injuries and fatalities from crashes [5]. Thus, there is a need to improve road and pedestrian safety through effective communication of traffic sign messages to increase traffic sign comprehension.

The lack of traffic comprehension has resulted in some associated risks which have become a major concern in many countries. In Metro Manila, disregarding traffic signs was the major cause of traffic accidents and violations based on the 2017 Accomplishment Report of the Metropolitan Manila Development Authority [6], a government agency in charge of transport and traffic management in Metro Manila. In 2017, disregarding traffic signs was the number one cause of traffic violations, with over 91,000 cases, an increase of almost 37,000 cases compared to 2016 (See Table 1)[6]. Likewise, disregarding traffic signs was the number two cause of accidents in the region, with 27,651 cases of accidents or 30 percent of the total accidents in 2017 (See Figure 1)[6]. Thus, this study was conducted to analyze if drivers and nondrivers (treated as pedestrians) disregard traffic signs due to low comprehension of traffic signs. Therefore, selecting effective countermeasures to improve road and pedestrian safety is a critical component in addressing the continuous road traffic violations and accidents in Metro Manila.

Table 1. Top 10 Traffic Violations in Metro Manila, 2016 and 2017.

Rank	Violation	2016	2017	Difference
1	Disregarding Traffic Sign	54,917	91,843	36,926
2	Obstruction	45,729	73,082	27,353
3	Unified Vehicle Reduction Program	22,503	30,474	7971
4	Illegal Parking (not towed)	20,467	26,110	5643
5	Illegal Parking (towed)	14,222	19,126	4904
6	Loading/Unloading in Prohibited Zone along EDSA	7077	11,888	4811
7	Truck Ban	7032	9604	2572
8	Stalled Vehicle	7568	8253	685
9	Reckless Driving	6532	7754	1222
10	Private Vehicle Using Yellow Lane	-	7671	-
	Motorcycle Lane (Commonwealth)	6373	-	-

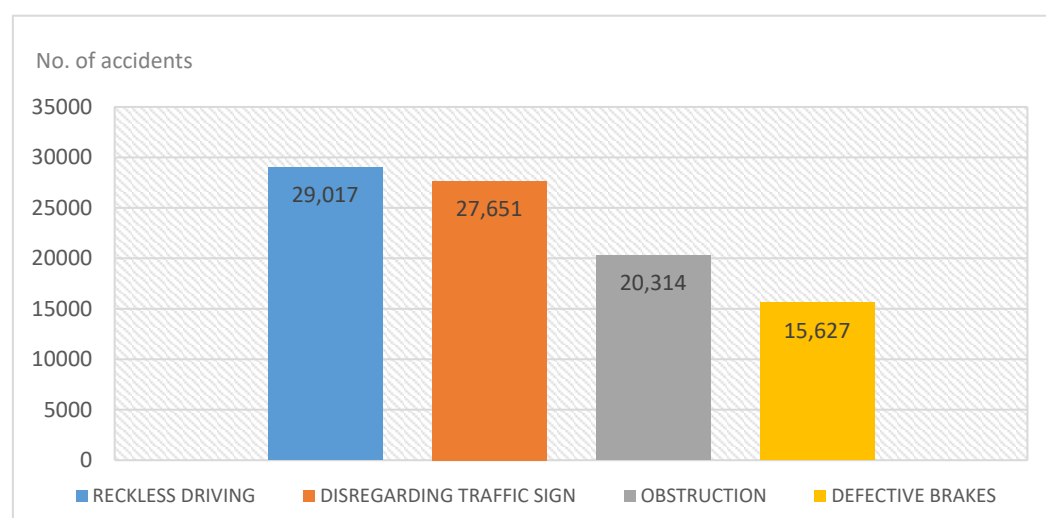


Figure 1. Major causes of vehicular accidents in Metro Manila, 2017.

One effective countermeasure is through the proper communication of traffic sign messages which depends on how these traffic signs are designed, using symbols with different shapes along with text or words [7]. Collins and Lerner [8] suggested the use of pictorial symbols in traffic signs, since they can effectively convey complex information using limited resources, are more easily identifiable than words from a greater distance and support the better performance of memory tasks compared to text. Because symbols provide a language-free method of communicating, they can potentially be understood by diverse groups which vary in life experience and reading ability [9]. Wiseman et al. [10] mentioned that when both symbols and verbal codes are provided, memory quality is improved because of the synthesis of the details of the symbols and texts. In the comprehension of traffic sign context, Shinar and Vogelzang [11] found that adding text to symbols can improve the driver's comprehension levels and reduce the time it takes to comprehend traffic signs.

Designing traffic signs also requires the standardization of shapes so that various signs can easily be recognized and can provide immediate information to drivers and pedestrians. For example, the circle symbol is mainly used for regulatory signs that inform road users of traffic laws and regulations, which, if disregarded, will constitute an offense [12]. Examples of regulatory signs are those identified as priority (obligation to give way at intersections), speed (speed limit limitations), direction (indicating the direction to follow), prohibitive (prohibition of movements at intersections), parking (control of vehicle parking), and miscellaneous (not covered in other categories, such as no blowing of horns) [12]. The equilateral triangle symbol with one point vertically upward is used for warning signs. Warning signs communicate information regarding potential hazards and intend to help reduce or eliminate the associated risks [13]. For example, the horizontal alignment signs assist drivers in negotiating curves safely and to indicate the direction and approximate degree of the turn required [14]. These characteristics are an important consideration in designing regulatory and warning signs to convey the intended information.

When a regulatory or warning sign does not clearly convey its intended information, the rate of comprehension is relatively low, ranging from 17 to 37 percent [15]. Thus, most of these signs are poorly understood [16], while some even having their meaning perceived as the opposite of the true meaning [17–19]. In a study by Drory and Shinar [20], drivers' comprehension of warning signs, like crossroads, school crossings, and sharp curves, showed that only 9% of drivers could comprehend the correct sign. Also, drivers routinely have difficulties in understanding the meaning of warning signs, such as 'slippery when wet', 'road narrows', 'steep descent', 'pavement ends', and 'truck crossing', with correct response rates ranging from 6 to 40% [21–23]. Brucal et al. [24] also found low comprehension scores for 20 regulatory signs. To improve comprehension, these 20 signs were redesigned using ergonomic design principles and obtained significantly higher comprehension level ratings, which is relevant in conveying safety information.

To standardize safety signs and safety markings conveying safety information, the International Organization for Standardization (ISO) developed ISO 3864-1:2011 [25]. ISO 3864-1:2011 established the safety identification of colors and design principles to be used in workplaces and public areas for the purpose of accident prevention, fire protection, health hazard information, and emergency evacuation. This standard also describes how symbols should be displayed with supplemental text, multiple images for more than one potential hazard, and the safe viewing distances for compliant signs and labels. Aside from considering sign features that are self-evident (e.g., colors and shapes), or those that can be identified only in relation to other icons (e.g., distinctiveness), icon features such as familiarity, concreteness, complexity and semantic distance are of central concern in traffic sign research [26]. Familiarity is defined as the frequency of encounter or use in daily lives. According to Rosson [27], signs that are familiar would be better

comprehended by users. Concreteness means that the sign depicts objects which have obvious connections with the real-world—better signs are more concrete, whereas ambiguous signs are difficult to understand [28]. Complexity is something related to the details and elements of the sign—a sign that contains a lot of detail or is intricate is complex, while simple signs contain fewer elements or little detail [29]. Semantic distance refers to the distance of the relationship between what is depicted in the sign and the function it is intended to represent [30]. These icon features are very important, particularly for testing the sign's comprehensibility.

To test a sign's comprehensibility, several methodologies have already been used with different test formats. For instance, ISO 9186-1:2007 [31] proposes the open-ended test format, in which participants were asked to describe the meaning of the sign in their own words [4]. However, the problem with this method is the subjective evaluation of the responses, especially if these are going to be corrected by different judges [32]. Also, an open-ended test format allows for partially correct answers, but the effectiveness of traffic signs is based on the full understanding of their meaning, and not on partial understanding [4,19]. Thus, other methods have been employed in evaluating the comprehensibility of traffic signs, such as multiple-choice tests [28], and matching tests [33]. In using the multiple-choice format, the quality of distractors (wrong answers) is very important since this could greatly influence the comprehension scores. When the wrong answers could easily be ruled out, the respondents can easily choose the correct answer, and this would unfairly inflate the comprehension score [34,35]. In a matching test, the traffic sign is matched with the most appropriate referent name, which shows a clear-cut distinction between correct and incorrect answers. The use of a matching test also assists respondents who lack writing and expressing abilities, and this reduces the answering time and analysis cost [32]. To assess the sign's acceptability in a matching test, a level of at least 67% accuracy must be obtained in a comprehension test [24,25]. This level of accuracy was also adopted in other traffic comprehension studies [17,18,23,24,32], particularly for reducing the associated risks brought about by the lack of traffic comprehension.

A review of previous research indicated that there were no studies of traffic sign comprehension addressing the issue of driving experience (drivers vs. nondrivers) in the Philippines. In addition, drivers and nondrivers were selected to derive the proper baseline performance, and to evaluate the beneficial effect of driving experience on recognizing the different traffic sign types (regulatory and warning) and display condition (symbol, text, text and symbol). Cognitive design features were also assessed to measure the sign's design through concreteness, complexity, familiarity and semantic distance, including the relationship between cognitive design features, traffic sign types and display conditions. Although we adopted the matching test experiment from Chi and Dewi [33], this was the first time that the matching test was applied in the measurement of traffic sign comprehension, using matching accuracy and matching time, with percentage and seconds as units of measurement, respectively.

2. Methodology

2.1. Participants

Sixty participants aged between 18 and 57 years old (mean = 32.0, S.D. = 9.9) participated in this experiment. All participants were students or employees of Mapua University, in Manila. The participants consisted of two different groups: 30 participants with driving experience (drive almost every day) and 30 participants without driving experience (never driven a car). Those participants without driving experience were also treated as regular pedestrians which would require some level of traffic sign comprehension. The participants with driving experience consisted of 21 males and 9 females aged 21 to 58 (mean = 34.0, S.D. = 10.3). The group without driving experience was composed of 17

males and 13 females aged 18 to 56 (mean = 30.1, S.D. = 9.4). In terms of educational attainment, 12 participants were high school-level graduates, 29 were college undergraduates, and 19 were college graduates (Table 2). Prior to the experiment, all participants were briefed about the objectives of the experiment and practiced the matching test routine.

Table 2. Demographic Characteristics of Participants.

Demographic Characteristics	Categories	Drivers		Non-Drivers		All	
		No.	%	No.	%	No.	%
Age	18–27	11	18%	13	22%	24	40%
	28–37	8	13%	10	17%	18	30%
	38–57	11	18%	7	12%	18	30%
Gender	Male	21	35%	17	28%	38	63%
	Female	9	15%	13	22%	22	37%
Educational Attainment	High School Level	6	10%	6	10%	12	20%
	College Undergraduate	14	23%	15	25%	29	48%
	College Graduate	10	17%	9	15%	19	32%

2.2. Equipment and Computer Programs

A computer program was developed using Netbeans UDE 5.2 written in Java programming language, which specifically ran through a JAVA SE application program. The experiment took place in the Computer Integrated Manufacturing (CIM) Laboratory of the university where the study was set. The first part of the program asked about the participants' personal characteristics and driving experiences. The second part was a matching experiment based on the 73 traffic signs, to determine the comprehension and matching time of the participants.

2.3. Procedures

The experiment was conducted according to the National Ethical Guidelines 2017, of the Philippine Research Ethics board. Prior to the experiment, the participants were required to fill out a consent form, including the personal characteristics such as age, gender, educational attainment, as well as their personal driving experiences. For those with driving experience, the participants were also asked about their driving characteristics, such as frequency of driving, number of licensed driving years, and whether they attended driving schools. For nondrivers, they could skip the questions on driving experience and proceed immediately to the matching test. The instructions, survey form, and the matching test materials were all written in English.

After submitting the required information, the participants were directed to the matching test screen to assess the comprehensibility of the 73 traffic signs. As shown in Figure 2, the selection of traffic signs was based on the location of major roads, such as the C-5 road in Quezon City, where most of the violations and accidents occurred. Seventy-three traffic signs were selected and then categorized according to their traffic sign type and display condition (See Figure 3), to determine if these factors influence a driver's comprehension. The current study adopted the matching test format from Chi and Dewi [33], where the participants matched the traffic sign with the most appropriate referent name based on "Highways safety design standards Part 2: Road signs and pavement markings" by the Department of Public Works and Highways [12].

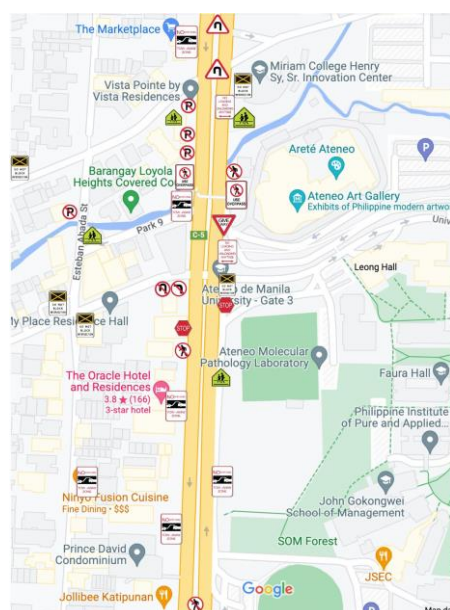


Figure 2. Some of the traffic signs posted along C-5 road in Quezon City.

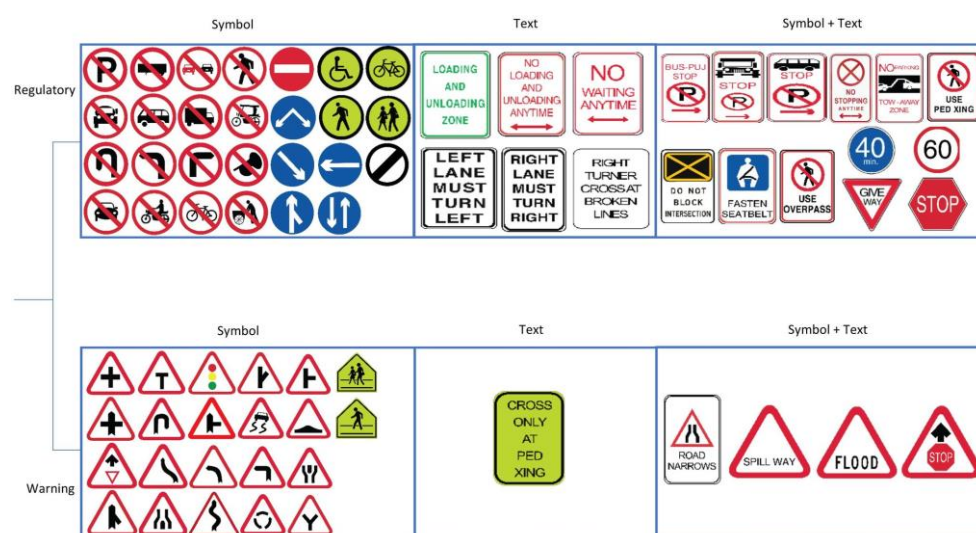


Figure 3. Traffic signs classification based on traffic sign type and display condition.

For the matching test, the 73 traffic signs were divided into three groups. The order of the traffic signs was randomized, but signs that were expected to have a similar referent name were included in one group to minimize guessing from participants. When the traffic sign was flashed on the screen, the participant had to click the letter that corresponded to the referent name of the traffic sign on the screen. If the referent name matched the traffic sign, the time it took the participant to click the letter was recorded as the matching time. Otherwise, matching time was not recorded for the incorrect referent name.

The second part of the experiment was about the subjective rating of the cognitive design features for the 73 traffic signs, which were also assessed to measure the effectiveness of the sign's design. Participants were given an evaluation sheet to give subjective ratings between 1 and 5 points for familiarity (1 = very unfamiliar, 5 = very familiar), concreteness (1 = definitely abstract, 5 = definitely concrete), complexity (1 = very complex, 5 = very simple), and semantic distance (1 = very weakly related, 5 = very strongly related) for each traffic sign presented in color and printed in English on the sheet. For example, when the "No Parking" sign was shown, the participant was asked to assess the traffic sign based on concreteness. This was repeated with all remaining traffic signs until all

signs had been assessed using the four cognitive design features. The definition for each cognitive design feature, as well as the rating scale, were included on the evaluation sheet, as shown in Figure 4.



CONCRETENESS if they depict real objects, materials, or people.

ABSTRACT are those that do not depict real objects.

5 - Definitely concrete
4 - Somewhat concrete
3 - Neither concrete nor abstract
2 - Somewhat abstract
1 - Definitely abstract

1.	5	4	3	2	1		26.	5	4	3	2	1		51.	5	4	3	2	1
2.	5	4	3	2	1		27.	5	4	3	2	1		52.	5	4	3	2	1
3.	5	4	3	2	1		28.	5	4	3	2	1		53.	5	4	3	2	1

Figure 4. Sample evaluation sheet for cognitive design features.

2.4. Data Analyses

The 60 participants in the study were asked to match the 73 traffic signs based on the given referent names. If the referent name matched the traffic sign, then the time it took the participant to click the correct referent name was recorded as the matching time. Otherwise, matching time was not recorded for the incorrect referent name. In addition, the 60 participants were also requested to assess the 73 traffic signs using the four cognitive design features.

To examine how traffic sign type and display condition were related to their comprehension by drivers and nondrivers, various statistical analyses were utilized to analyze the data. Statistical analyses were run with Minitab 19. To determine the effects of traffic sign type (regulatory signs vs. warning signs) and display condition (symbol, text, text and symbol) on the comprehension level of drivers and nondrivers, a two-way ANOVA was conducted, as well as post hoc *t*-tests. The primary dependent variables were matching accuracy and matching time measured in percentage and seconds, respectively. For cognitive design features, Pearson correlations were conducted to examine the inter-relationship of cognitive design features with traffic sign type and display condition. ANOVA and post hoc *t*-tests were also utilized to determine significant differences between categories. The statistical significance criterion for the study was set at $p \leq 0.05$.

3. Results

3.1. Matching Accuracy

Out of the 73 traffic signs used in the experiment, 27 (or 37%) signs did not pass the 67% comprehension test pass rate set by ISO 3864-1:2011 [24], as shown in Table 3. The 27 signs that failed can be broken down to 11 regulatory signs and 16 warnings signs. However, 24 out of the 27 signs that failed were signs displayed in symbols, which were often miscomprehended

Table 3. The evaluation result of the traffic signs based on the 67% passing rate set by ISO 3864-1:2011.

Traffic Sign Type	Above 67%				Below 67%			
	Symbol	Text	Symbol+Text	Total	Symbol	Text	Symbol+Text	Total
Regulatory	19	6	10	35 (76%)	8	0	3	11 (24%)
Warning	6	1	4	11 (41%)	16	0	0	16 (59%)
Total	25	7	14	46 (63%)	24	0	3	27 (37%)

In terms of matching accuracy, four (4) regulatory signs obtained a 100% matching accuracy, namely  minimum speed limit of 40,  no waiting anytime,  left lane must turn left, and  no entry for cars. For warning signs,  road narrows obtained

Table 4. Matching accuracy and matching time for regulatory and warning signs.[illegible]

Types of traffic sign	67% and above				Below 67%					
	No.	Picture	Sign Meaning	Rate	No.	Picture	Sign Meaning	Rate	Rate	
Warning	1		ROAD NARROWS	98%	4.25	1		CROSS ROAD	55%	7.61
	2		SPILL WAY	95%	4.91	2		CURVE	55%	8.24
	3		FLOODING AREA AHEAD	95%	4.37	3		WINDING ROAD	48%	7.55
	4		Y JUNCTION	93%	3.80	4		SHARP TURN	47%	14.36
	5		SLIPPERY ROAD	93%	5.79	5		DIVIDED ROAD	40%	8.46
	6		ROUNDBOUT	92%	5.45	6		END DIVIDED ROAD	33%	11.45
	7		HUMPS AHEAD	90%	5.15	7		SIDE ROAD RIGHT JUNCTION	30%	9.61
	8		T JUNCTION	87%	6.10	8		PEDESTRIAN AHEAD	27%	10.50
	9		STOP AT INTERSECTION AHEAD	87%	10.00	9		REVERSE CURVE	23%	34.36
	10		CROSS ONLY AT PEDESTRIAN CROSSING	85%	4.84	10		PRIORITY CROSS ROAD	22%	16.38
	11		SIGNAL AHEAD	80%	13.9	11		GIVE WAY AT INTERSECTION AHEAD	17%	23.40
					12		CHILDREN AHEAD	15%	6.00	
					13		SHARP JUNCTION	13%	8.38	
					14		HAIR PIN CURVE	10%	8.83	
					15		SIDE ROAD JUNCTION	7%	14.75	
					16		T AND Y JUNCTION	2%	21.00	

The current study also investigated the effects of traffic sign type and display condition on the comprehension of drivers and nondrivers. In terms of traffic sign type, drivers had higher matching accuracies for both the regulatory and warning signs compared to nondrivers. For the regulatory signs, the matching accuracy of drivers was higher at 79.93% compared with nondrivers at 75.87%, which was significantly different at $p = 0.033$ (Table 5). On the other hand, warning signs tended to be more difficult to comprehend, as reflected by a lower matching accuracy of drivers and nondrivers at 56.05 and 48.77%, respectively.

Table 5. Matching accuracy of drivers and nondrivers vs. traffic sign types.

Traffic Sign Types	Matching Accuracy (In Percent))				F-Test	<i>p</i> -Value
	Drivers		Non-Drivers			
	Mean	SD	Mean	SD		
1. Regulatory	79.93	8.33	75.87	5.83	4.78	0.033 *
2. Warning	56.05	10.28	48.77	10.30	7.52	0.008 *
F-test	97.73		157.37			
<i>p</i> -value	0.000 *		0.000 *			

* values indicate statistical significance at $p < 0.05$.

In terms of display condition, signs that were represented by symbols had the lowest matching accuracy, with drivers registering at 61.97%, which was significantly different to nondrivers at 55.03% ($p = 0.004$) (Table 6). Although there was no significant difference between drivers and nondrivers for both text and combination of text and symbol, matching accuracy was still the best with text only, at 92.86% for drivers and 91.90% for non-drivers. However, for both drivers and nondrivers, the matching accuracy for signs

displayed in text and signs displayed in text and symbol were both significantly different from those signs displayed in symbols only.

Table 6. Matching accuracy of drivers and nondrivers vs. display condition.

Display Conditions	Matching Accuracy (In Percent)				F-Test	<i>p</i> -Value
	Drivers		Non-Drivers			
	Mean	SD	Mean	SD		
1. Symbol	61.97	8.88	55.03	9.10	8.93	0.004
2. Text	92.86	13.91	91.90	10.40	0.09	0.765
3. Symbol+Text	88.43	9.46	86.27	8.22	0.89	0.350
F-test	7.43		9.01			
<i>p</i> -value	0.001 *		0.000 *			
Groups differed	1 & 2		1 & 2			
significantly at 0.05 level	1 & 3		1 & 3			

* values indicate statistical significance at $p < 0.05$.

3.2. Matching Time

Matching time was recorded when the referent name was correctly matched to the traffic sign. For regulatory signs that passed the 67% comprehension test, the mean matching time ranged from 2.71 to 10.14 s (shown in Table 4), with  “Bike Lane” being matched with the fastest time of 2.71 s, followed by  “Left lane must turn left” at 3.32 s and  “No Left Turn” at 3.55 s.  “Minimum Speed of 40” obtained the lowest matching time among the regulatory signs at 10.14 s. For warning signs, the matching time was slightly higher, ranging from 3.80 to 13.90 s.  “Y Junction” was matched at 3.80 s, then  “Road Narrows” at 4.25 s and  “Flooding Area Ahead” at 4.37 s.  “Signal Ahead” was matched with the slowest time of 13.90 s.

For traffic signs that did not reach the 67% matching accuracy, the mean matching time ranged from 2.71 to 34.36 s. Some traffic signs obtained a mean matching time of less than 10 s, but only a few were able to match them correctly. For  “Speed derestriction,” no matching time was recorded, since none of the participants matched it correctly.

When matching time was analyzed through traffic sign type, the results showed that there was no significant difference in matching time between drivers and nondrivers for both regulatory and warning signs. However, drivers took less time in matching the signs with their referent names than nondrivers. On the other hand, matching time between regulatory and warning signs showed a significant difference for both drivers and non-drivers. Drivers took a longer time in matching warning signs at 7.35 s, than matching the regulatory signs at 5.67 s. Similarly, nondrivers took a much longer time to match warning signs at 8.16 s, than regulatory signs at 5.87 s (Table 7).

Table 7. Matching time of drivers and nondrivers vs. traffic sign types.

Traffic Sign Type	Matching Time (In Seconds)				F-Test	p-Value
	Drivers		Non-Drivers			
	Mean	SD	Mean	SD		
1. Regulatory	5.67	2.39	5.87	1.97	0.13	0.724
2. Warning	7.35	3.84	8.16	3.29	0.78	0.382
F-test	4.13		10.75			
p-value	0.047 *		0.002 *			

* values indicate statistical significance at $p < 0.05$.

Table 8 shows that there was no significant difference in matching time between drivers and nondrivers, for all types of display conditions. However, signs represented by symbols had the longest matching time compared to other display conditions. In terms of driving experience, drivers had shorter matching time at 6.84 s compared with nondrivers at 6.98 s (Table 8). When text was added to the symbol, the matching time of drivers was faster at 5.49 s, compared to 6.02 s for nondrivers. Matching time was still best with text only, at 4.63 s and 5.24 s for drivers and nondrivers, respectively. In terms of display condition, the matching time of signs displayed in symbols was significantly different to those signs displayed in text, both for drivers and nondrivers.

Table 8. Matching time of drivers and nondrivers vs. display condition.

Display Condition	Matching Time (In seconds)				F-Test	p-Value
	Drivers		Non-Drivers			
	Mean	SD	Mean	SD		
1. Symbol	6.84	3.17	6.98	2.06	0.04	0.834
2. Text	4.63	1.75	5.24	2.32	1.34	0.252
3. Symbol+Text	5.49	2.94	6.02	2.49	0.57	0.452
F-test	5.14		4.33			
p-value	0.008 *		0.016 *			
Groups differed	1 & 2		1 & 2			
significantly at 0.05 level						

* values indicate statistical significance at $p < 0.05$.

3.3. Cognitive Design Features

To determine the cognitive design features which have affected sign comprehension, the Pearson correlation between matching accuracy and matching time, based on traffic sign type and display condition, was obtained. Table 9 showed that cognitive design features were positively correlated to matching accuracy for both regulatory and warning signs, and negatively correlated to matching time for warning signs. Matching accuracy for warning signs produced the highest Pearson correlation value ($r = 0.703$) when correlated to concreteness. On the other hand, semantic distance obtained the highest correlation value ($r = 0.777$) for regulatory signs in the matching accuracy. Familiarity also had a positive relationship with matching accuracy, which was also a good predictor for comprehension, especially when familiar symbols were used. For matching time, familiarity was the best predictor for warning signs (Table 9).

Table 9. Pearson Correlation for Cognitive Design Features and Traffic Sign Types.

Cognitive Design Features	Matching Accuracy				Matching Time			
	Regulatory		Warning		Regulatory		Warning	
	r	Sig	r	Sig	r	Sig	r	Sig
Concreteness	0.700	0.000 *	0.703	0.000 *	−0.232	0.120	−0.737	0.000 *
Complexity	0.726	0.000 *	0.634	0.000 *	−0.254	0.088	−0.568	0.002 *
Semantic Distance	0.777	0.000 *	0.696	0.000 *	−0.213	0.155	−0.681	0.000 *
Familiarity	0.651	0.000 *	0.410	0.034 *	−0.033	0.827	−0.453	0.018 *

* values indicate statistical significance at $p < 0.05$.

To determine the relationship between cognitive design features and display condition, Pearson correlation was also obtained between matching accuracy and matching time. For signs displayed in symbols, the results showed that cognitive design features were positively correlated to matching accuracy, and negatively correlated to matching

time. Matching accuracy of signs displayed in symbols obtained the highest Pearson correlation value ($r = 0.801$) when correlated to semantic distance, while matching time had the highest Pearson correlation value ($r = -0.440$) when correlated to familiarity (Table 10). On the other hand, cognitive design features were not correlated to matching accuracy and matching time when text was included in the signs. The results suggested that cognitive design features were more relevant to signs displayed in symbols.

Table 10. Pearson Correlation for Cognitive Design Features and Display Conditions.

Cognitive Design Features	Matching Accuracy						Matching Time					
	Symbol		Text		Symbol + Text		Symbol		Text		Symbol + Text	
	r	Sig	r	Sig	r	Sig	r	Sig	r	Sig	r	Sig
Concreteness	0.764	0.000 *	−0.372	0.411	0.046	0.861	−0.590	0.000 *	−0.056	0.906	0.412	0.100
Complexity	0.731	0.000 *	0.704	0.078	0.430	0.085	−0.487	0.000 *	−0.192	0.629	0.661	0.004 *
Semantic Distance	0.801	0.000 *	−0.187	0.688	0.090	0.732	−0.543	0.000 *	0.423	0.344	0.470	0.057
Familiarity	0.680	0.000 *	−0.275	0.550	−0.013	0.959	−0.440	0.000 *	0.255	0.582	0.158	0.544

* values indicate statistical significance at $p < 0.05$.

To analyze the cognitive design features of each traffic sign, Table 11 shows the signs with the highest and lowest ratings based on cognitive design features.  “Give way at intersection ahead” received the lowest concreteness and complexity rating with 2.53 and 2.50, respectively. The participants perceived the sign as somewhat abstract and moderately complex.  “Speed derestriction” also received the lowest rating in the semantic distance with 2.72, since the design of the icon was far from its intended meaning. Among the signs that received the lowest design evaluation,  “Speed derestriction” also received the lowest rating in familiarity at 2.40, since none of the participants matched it correctly, which might be because of the familiarity factor. For the highest ratings,  “Fasten Seatbelt” was rated as definitely concrete, with a rating of 4.63, which also received a high matching accuracy of 98%. The sign that was rated as simple was  “Stop”, with a rating of 4.68 and a matching accuracy of 95%.  “No Stopping Anytime” was rated as very strongly related to its intended meaning, with a rating of 4.83, and 98% matching accuracy.  “Loading and Unloading Zone” was rated as very familiar, with a 4.97 rating and 87% matching accuracy.

Table 11. The Highest and Lowest Ratings Based on Cognitive Design Features.

Cognitive	Highest Rating				Lowest Rating			
Design Features	Regulatory		Warning		Regulatory		Warning	
Concreteness	 FASTEN SEATBELT 4.63	 CROSS ONLY AT PED XING 4.33	 SPEED DE-RESTRICTION 2.70	 GIVE WAY AT INTERSECTION AHEAD 2.53				
Complexity	 STOP 4.68	 SPILL WAY 4.40	 SPEED DE-RESTRICTION 2.97	 GIVE WAY AT INTERSECTION AHEAD 2.50				
Semantic Distance	 NO STOPPING ANYTIME 4.83	 NO LEFT TURN 4.77	 SPEED DE-RESTRICTION 2.72	 STOP AT INTERSECTION AHEAD 2.78				
Familiarity	 LOADING AND UNLOADING ZONE 4.97	 CROSS ONLY AT PED XING 4.63	 SPEED DE-RESTRICTION 2.40	 GIVE WAY AT INTERSECTION AHEAD 2.68				

4. Discussion

With the increasing cases of traffic violations and accidents in Metro Manila, the current study examined the comprehension of Filipino drivers and nondrivers of the 73 existing traffic signs for their matching accuracy, matching time, and cognitive design features. Since several studies have already investigated the effects of age, gender and educational attainment on the comprehension level of traffic signs, these were not analyzed in the current study, as they all fall under the non-design category of comprehensibility. While drivers' characteristics may have a significant effect on comprehensibility, this study focused on the design factors, such as the type and display conditions, which are more flexible to modifications than the characteristics of drivers.

The results of the study showed that signs displayed in text may have higher matching accuracy, but not necessarily with faster matching times. For example,  "Left lane must turn left" obtained a 100 percent matching accuracy, but it was the  "Bike Lane" sign, which was displayed in symbol form, which was matched the fastest at 2.71 s. Similarly,  the minimum speed limit of 40 sign obtained a 100 percent matching accuracy, but it also registered one of the slowest matching times at 10.14 s. While some traffic signs were fully comprehended, the effect of late reaction could affect the driver's preparedness and subsequent responsiveness to events [36]. Thus, traffic sign effectiveness is not only attained through comprehension matching accuracy, but also through comprehension matching time.

Traffic signs are designed to prevent accidents and help road users adapt to the environment easily. However, almost thirty-seven percent of the 73 traffic signs failed to meet the 67% comprehension test passing rate set by ISO 3864-1:2011 [25]. Between the two types of traffic signs, warning signs were more often miscomprehended, especially those presented in symbols. Symbolic signs are often misunderstood by drivers, even those that have already been standardized and used throughout the world [14]. For example, Picha et al. [37] found that low comprehension levels existed for several traffic symbols when evaluated by more than 3000 drivers in Texas. The use of symbols is sometimes preferred because it facilitates large amounts of information (relative to text occupying similar surface area) and avoids varying language and reading abilities among users. However, most of these symbols are poorly designed and difficult to understand [16,28]. Lack of understanding may reduce its intended purpose and may lead to violations and road accidents, including errors in making predictions about other road users' actions [38,39].

To increase the comprehension of traffic signs, there is a need to redesign signs that failed the 67% comprehension standard, which were mostly symbolic signs. The proposed designs should be direct, simple, and closely related to the meaning by considering user perceptions [40,41]. With user participation in the design process, signs are more likely to be interpreted correctly by the intended meaning because they were directly mapped from the mental models of users [42,43]. However, redesigning the traffic sign based on the user's perception is not enough because everyone has a different perception. Banares et al. [19] incorporated ergonomic principles in redesigning the 21 poorly designed road warning signs in the Philippines. The redesigned alternatives led to substantial improvements in the comprehension level of drivers. Therefore, the 27 traffic signs that failed the 67% comprehension standard should also be redesigned, incorporating cognitive design features to increase comprehension scores.

Traffic signs which received the lowest ratings in cognitive design features were mostly in a symbol format. For instance,  "Give Way at Intersection Ahead" and  "Speed derestriction" both received the lowest ratings in concreteness, complexity, and familiarity. Consequently, these signs were also poorly comprehended;  "Give Way at Intersection Ahead" obtained a 17% matching accuracy, while none of the participants matched the  "Speed derestriction" correctly. In terms of semantic distance, 

“Speed derestriction” also received the lowest rating at 2.72, the only traffic sign that obtained a semantic distance rating of below 3.0. The low rating can be attributed to its design which was very far from its intended meaning. For instance,  “Speed derestriction” can be confused with the symbolic “No-entry” sign, which was very far from its referent name of end of speed restriction. It should be noted that one important criterion for good sign design is its ability to induce comprehension of its meaning when being encountered for the first time (e.g., seeing the sign by nondrivers for the first time). However, even those with driving experience found difficulty in comprehending the meaning of this sign.

On the contrary, the  “No Right Turn” sign was comprehended well, obtaining a 98% matching accuracy. This is because the comprehension of drivers focuses on how consistent the sign symbols are to their cognitive expectations [18]. Paninti [44] compared several alternative symbols used to signify work zones and found that symbols with a good physical resemblance to what they are meant to signify were all well understood, even when the details of these symbols were different. In contrast, when the intended message was different to how it was conveyed symbolically, all proposed alternative symbols were not clearly understood [44]. Therefore, the closer the semantic meaning of the sign, the higher the comprehension level.

Furthermore, the cognitive design feature ratings were also seen to be highest in semantic distance and concreteness. This was further validated by multiple regression analyses wherein semantic distance was associated with matching accuracy, while concreteness and familiarity were significant for predicting matching time (Table 12). Interestingly, semantic distance alone contributed 59.53% in predicting matching accuracy, but semantic distance was not significant in predicting matching time. On the other hand, concreteness can explain 38.28% of the variance, while familiarity contributed 4.68% in predicting matching time. Thus, to improve comprehension performance, semantic distance, concreteness, and familiarity are the key cognitive design features that must be considered by designers. Specifically, this study found that semantic distance is the most significant predictor for matching accuracy, which was also the result obtained by other traffic comprehension studies [3,45]. For matching time, concreteness and familiarity are the best predictors, especially for warning signs, but also for signs displayed in symbols.

Table 12. Multiple regression analysis for matching accuracy and matching time.

Predicting factor	Matching Accuracy			Predicting Factor	Matching Time		
	Coefficient	p-Value	Contribution		Coefficient	p-Value	Contribution
Constant	−1.05	0.000	59.53%	Constant	23.85	0.000	42.96%
Semantic Distance	0.42	0.000	59.53%	Concreteness	−6.72	0.000	38.28%
				Familiarity	2.50	0.000	4.68%

When changing the symbol was deemed impractical (e.g., when it was already consistent with international code), it is recommended to add text above or below the symbol to give drivers more opportunities to understand the meaning and to retain the information in memory [11]. Interestingly, signs displayed in text using the local language resulted in better comprehension compared to other display conditions [11]. In this study, signs in textual format were comprehended well by the Filipino participants since they can easily understand the texts which all were written in English. Since the application of the text is culture dependent, the use of variable message signs (VMS) technology can be used to display the text in different languages and can be placed at key decision points to facilitate better comprehension of drivers and nondrivers [46]. Within countries, sign improvements have focused on ensuring both the consistency of design and the standardizing of sign design across countries and cultures [47].

To resolve the issue of comprehension between drivers and nondrivers, Lesch [16] suggested the conduct of training to enhance the users' comprehension, especially for some symbolic signs that were difficult to comprehend. In the study of Ramakrishnan et al. [48], they studied the differences in comprehension and matching time on airport safety signs before and after training. The participants' comprehension and matching time for symbolic signs were enhanced after recognition and recall training. Ou and Liu [3] also found that training significantly enhanced sign comprehension from an average comprehension score of 52% before training to 94% immediately after training. In addition, Wogalter et al. [49] studied comprehension differences of pharmaceutical and industrial-safety signs before and after training and found that the comprehension of difficult signs before the training was 54% for the former and 34% for the latter, but this improved to 87% and 63%, respectively, six months after the training. Although there are cases when the comprehension level drops after a month [49,50], it is still better compared to the comprehension level before training.

Hung and Huyen [51] explained that combining enforcement with education and training will have long-term effects on driver attitudes towards comprehension. Thus, educating all road users through continuous education or the retraining of drivers is a must. Ben-Bassat and Shinar [52] also recommended that a test of traffic sign meaning should be considered as part of a relicensing process for drivers, to verify that they are familiar with new signs, and to refresh their memory on sign meanings in general. Thus, adapting retraining in license application and renewal in the country may help road users improve or sustain their knowledge regarding traffic signs. Therefore, the matching test developed in this study could be adopted as a mandatory retraining requirement for the renewal of drivers licenses by the Land Transportation Office (LTO), the government agency in the Philippines responsible for the issuance of licenses and permits. Upon the application or renewal of a license, the driver could be asked to take the matching test as a mandatory retraining requirement, and only after obtaining a 67% comprehension score could their drivers license be released. Furthermore, the LTO could use the results of the matching test to regularly analyze the comprehension level of Filipino drivers to find out which signs are difficult to comprehend. Our matching-based comprehension test can also be applied and extended to evaluate existing traffic signs worldwide.

Aside from improving traffic sign comprehension, other strategies to improve road safety include the prediction of short-term traffic flow. Chen et. al. [53] evaluated the various smoothing models for cleaning anomalies in traffic flow data, which were further processed to predict short-term traffic flow evolution using artificial neural networks. The findings of the study provided efficient and accurate denoising approaches for short-term traffic flow prediction. In connection with traffic flow condition, Liu et al. [54] developed a novel operational design for flex-route transit services to reduce vehicle operations and improve the service quality of customers. The regime allowed the simultaneous dispatch of a certain number of modular autonomous vehicles (MAV) from a bus terminal at a departure time, where each MAV was allowed to visit customers freely outside of check-points.

5. Conclusions

Being familiar and aware of the meaning of traffic signs is considered the first step towards safer roads in Metro Manila. The current study examined 73 existing traffic signs in the Philippines for their matching accuracy, matching time, and cognitive design features. A total of 30 Filipino drivers and 30 Filipino nondrivers were voluntarily recruited to perform matching-based comprehension tests. The results of the experiment showed that 27 out of the 73 traffic signs did not achieve the 67% comprehension standard set by ISO 3864-1:2011. Drivers had better matching accuracy and matching time for both regulatory and warning signs compared to nondrivers. Traffic signs displayed in symbols had the lowest matching accuracies and the longest matching times, while the traffic signs displayed in text only had the highest matching accuracies and the fastest matching times.

When signs are displayed in symbols, drivers had higher matching accuracies compared to nondrivers.

The cognitive design features—concreteness, complexity, semantic distance, and familiarity—were all significant to matching time and matching accuracy. The cognitive design features were positively correlated to matching accuracy for both regulatory and warning signs, and negatively correlated to matching time for warning signs. For signs displayed in symbols, cognitive design features were also found to be correlated to matching accuracy and matching time.

To enhance the road user's comprehension of traffic signs, traffic signs with very low ratings (e.g., fail to reach at least 67% comprehension score) must be redesigned incorporating cognitive design features such as semantic distance, concreteness and familiarity. Familiar symbols and symbols which have physical representation should be used for the easier and faster comprehension of traffic signs. Signs in textual format were comprehended well by the Filipino participants, since they can easily understand the texts which were all written in English. Since the application of the text is culture dependent, the use of variable message signs (VMS) technology can be used to display the text in different languages and can be placed at key decision points to facilitate better comprehension by drivers and nondrivers.

This study could contribute to better road safety design standards in Metro Manila by developing targeted programs for drivers and nondrivers. The findings would also be very beneficial for highway and traffic authorities to better understand drivers' comprehension of various traffic signs. To guarantee an improved comprehension in the long run, the retraining and examination of drivers using the matching test developed in this study should be conducted. The Philippines' Department of Transportation could adopt the matching test of the current study as a mandatory retraining requirement for the application and renewal of drivers' licenses. Finally, our matching-based comprehension test could also be applied and extended to evaluate existing traffic signs worldwide.

Despite the clear and substantial contributions, the authors would like to acknowledge several limitations of this study. First, the demographics of the participants in terms of gender, age, and educational background were not analyzed, since these fall under the non-design category of comprehensibility. While drivers' characteristics may have significant effects on comprehensibility, this study focused only on the design factors, such as the type and display conditions, which are more flexible to modification than the characteristics of drivers. Second, the participants for the current study were limited to the employees and students of Mapua University. While we only recruited 60 participants for this study, we ensured that these participants were selected based on the primary objective of this study. Furthermore, the increasing cases of violations and accidents due to disregarding traffic signs was hypothesized to be caused by a lack of traffic comprehension. Studies have found that the neglect of road users and the lack of comprehension lead to the major human errors in traffic accidents. Given the huge importance of verifying the effectiveness of traffic signs within the context of road safety, future researchers could consider developing a regression model to determine the relationship between comprehension and traffic accidents.

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