Response Time and Decision Accuracy for 'No Turn on Red' Signs

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'No turn on red' signs have been the subject of traffic research in recent years because they are violated at higher rates than other signs. One reason may be due to inadequate conspicuity. This study examined response times and decision accuracy (proportion correct) following glance exposure to three different 'No Turn on Red' signs. Two of the 'No Turn on Red' signs tested are currently being used on U.S. roadways in some jurisdictions; one contains only text and the other contains a red circle with text. These were compared to a third "new" sign (Prohibition Arrow and Text). The three signs and a no-sign condition (control) were embedded into 12 different traffic scenes. Each sign and scene condition was presented for a 1 s duration and then participants responded whether they could turn right in that particular scene or not (answering yes or no). The new (Prohibition Arrow and Text) sign condition had significantly faster response times compared to the other two signs. Accuracy was approximately 90% and did not differ among sign conditions. The no-sign condition was responded to significantly slower and less accurately than the sign conditions. The new (Prohibition Arrow and Text) sign yielded better performance than the other sign conditions in scenes rated as highly cluttered. Some explanations on why the new sign benefited decision times are discussed.

INTRODUCTION

Traffic accidents create a large toll on human life. According to the National Center for Statistics and Analysis's Fatality Analysis Reporting System (FARS), there were over 39,000 deaths in the U.S. in 2005. One of the attributed causes is poor signage. Important factors for deficient signage include a lack of conspicuous features and conceptual cues for understanding. In many driving scenarios, the driver only has a short time to detect, interpret, and react. Well-designed signs should attract attention, expedite comprehension and motivate compliance. In attempts to enhance conspicuity, empirically-derived sign standards have been published for size, brightness, contrast and text parameters (Forbes, Snyder & Pain, 1972).

In examining the appropriate components of signs, several studies (Dewar, Ellis & Mundy, 1976; Kline, Buck, Sell, Bolan & Dewar, 1999; Kline, Ghali, Kline & Brown, 1990) have reported faster response times for signs with graphics (Symbols & Arrows), but a few studies report faster response times for Text-Only signs (Dewar, Ells, & Mundy, 1976; Shoptaugh & Whitker, 1984). Barnes, Levine and Wogalter (2000) examined interstate highway entrance-ramp direction signs. They found that two signs, one with an Arrow & Text, and one with Text-Only, were understood better than conventional Arrow-Only directional signs. These and other findings support the notion that having two (text and graphics) methods of information transmission, or codes, is better than one (Paivio, 1974) because having both codes provides somewhat more complete information (spatial/graphic supplemented by text). The additional benefit may be due to redundancy as well as enhanced breadth of information transmitted that is not given entirely in a single code or form.

These conclusions applied to other traffic signs may benefit roadway safety. One example of a frequently violated sign that could use improvement is 'No Turn on Red' (Podany, Wogalter, & Mayhorn, 2004). Violations are potentially hazardous to pedestrians and other vehicles traveling through an intersection with a green light (Preusser, Leaf, Debartla, & Blomberg, 1981). 'No Turn on Red' signs have been the subject of traffic research in recent years because of their relatively-high violation rate (Zegeer & Cynecki, 1986),

One study, relevant to the present research, was conducted by Podany, Wogalter, and Mayhorn (2004) which examined several different 'No turn on red' signs. Three of the tested signs were taken from the Manual on Uniform Traffic Control Devices (MUTCD, 2000), and the fourth sign was designed based on components found in warning and traffic signs. The graphic in this sign was comprised of a circle-slash prohibition symbol on top of a right turn arrow. Participants rated the likelihood that they would: (1) notice, (2) understand, and (3) comply with each of the four signs. Podany et al. (2004) found that people rated the newly designed sign better on all three scales than the three existing MUTCD signs.

Podany et al. (2004) interpreted their results to suggest that the new sign was better than the existing versions of the sign. However, their method involved ratings. As a method, ratings have limitations, as the findings may only weakly reflect actual phenomena. Nevertheless, studies involving ratings should not be ignored as behavioral intentions can be reasonably predictive of behavior (Wogalter & Dingus, 1999).

However, stronger evidence of a benefit of the new Prohibition Arrow and Text sign would supplement the results found in the Podany et al. study. One way to demonstrate better validity is to place the signs in a realistic traffic scene where task performance was measured in terms of accuracy and speed of response. In their report, Podany et al. (2004) noted that future research should do this. The present project is the operationalization of a more face valid study than was performed by Podany et al. (2004).

This study tested two of the three MUTCD signs used in Podany et al. (2004), together with the "new" sign that they developed. Color photographs of sign-containing various traffic scenes were presented each for 1 second and the participant responded 'yes' or 'no' to whether they could turn right. The sign conditions were formed by inserting into traffic scenes the different signs. In other words, each of the different sign conditions were inserted into the same scenes to control for context. This graphical manipulation was performed using computer software.

Predicted was that the new sign (Prohibition Arrow and Text) and the existing MUTCD Red Circle & Text would have faster response times than the existing MUTCD Text-Only sign condition as these two former signs include conspicuity features that the Text-Only sing does not have. Based on Podany et al.'s (2004) results, the new Prohibition Arrow and Text sign was predicted to be the best because it included a larger graphic, it broadcasted a larger area of red color, and it had bolder components present in the arrow symbol which should produce faster sign recognition (e.g., Wogalter et al., 1999). It also has the common prohibition symbol associated with the meaning "Don't" or "No." In the middle in terms of predicted performance would is the Red circle & Text because it has a graphic (i.e., circle shape) and red color, and thus should be more conspicuous relative to the Text-Only sign. However; the Red Circle & Text sign was expected to produce lower performance than the Prohibition Arrow and Text sign because the former sign's graphic is less distinctive than the latter. Thus, in concordance with Podany et al.'s (2004) ratings, the second best performance was predicted to be the Red Circle & Text sign, and worst, the Text-Only sign.

In addition, the present study also examined whether there would be a greater benefit of the the distinctive new sign in more cluttered environments in which attention might be captured by extraneous stimuli and search time delayed with less distinctive signs.
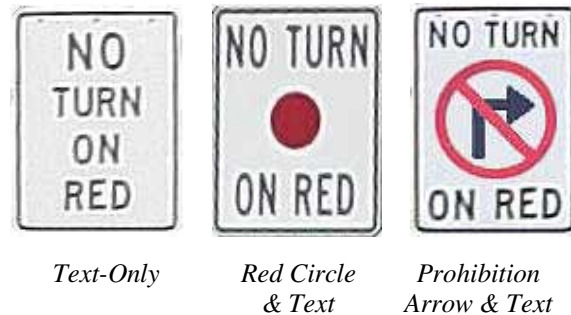
METHOD

Participants

Sixty two (62) students (25 male, 37 female) between the ages of 18 and 21 ($M = 18.26$, $SD = .651$) participated for credit in an introductory level psychology course at a large public university in the mid-Atlantic region of the U.S. All participants indicated currently having a valid U.S. driver's license.

Stimuli

Twenty-six color photos of traffic scenes were taken and labeled A-Z and separated into two groups; group 1 labeled A-L and group 2 labeled M-Z. Group 1 contained the experimentally manipulated stimuli and group 2 had extraneous stimuli. There were 4 sign conditions in group 1 (No-Sign, Text-Only, Red Circle & Text and the Prohibition & Text) and each participant saw all 48 conditioned stimuli and 12 filler scenes. Most scenes had an additional unrelated traffic sign in it. Figure 1 displays the sign conditions.

Figure 1. Representations of the three sign conditions.

Text-Only   Red Circle   Prohibition
            & Text   Arrow & Text

All scenes were photographed digitally at varying distances from the 'No Turn on Red' sign. Each scene was loaded into Paint Shop Pro X v10.02 where signs and scenes were manipulated to equalize brightness, contrast and color balance across scenes. All scenes were resized to fully fit onto a screen size of 36.8 cm (14.5 inch) wide X 27.9 cm (11 inch) high. Manipulated signs embedded in the scenes were color matched and resized to be congruent with any native signs already in the scene. All signs were placed in proper location according to the context of the scene and were generally around the upper middle areas, although never in the exact center or periphery. The scenes (12) varied in apparent visual complexity and traffic conditions. Supplemental analyses indicated that the scenes used varied in terms of clutter, contrast, placement, and noticeability. We identified several scenes rated "poor" and several rated "good" intersections which allowed us to test the effects of conspicuity associated with the 3 sign conditions. For all scenes with the No Turn on Red Signs present there was also a realistic version of the scene with the sign absent as part of the control condition. Brightness was adjusted to be the same across scenes. All sized signs were approximately 2.0 cm wide X 2.5 cm high and were 72 dpi bitmap files.

The 48 stimuli from group 1 with 12 filler stimuli from group 2 together were loaded into SuperLab Pro v2.04 which randomly ordered the scenes. Each photograph was presented for exactly 1000 msec (1 s). Results from pilot testing indicated that this exposure time was near the lower limit of apprehension for these fairly complex scenes. The scene filled the entire 43.2 cm (17") 800 x 600 pixel resolution of a Dell monitor. The approximate viewing distance was 76.2 cm (30 inch) for each participant.

Procedure

A consent form was initially signed by each participant who then sat down at a computer station and depressed the spacebar to begin the experiment. The first slide contained the general procedure and contextual information about what factors affect drivers' decisions when making a right-hand turn (e.g., pedestrians, traffic lights, etc.). This introduction slide informed the participant they would be shown a question (Can you make a right turn?) related to the subsequent traffic scene and they responded by pressing a key on the computer keyboard to indicate either a "yes" or "no" answer. Question slides were displayed for 4 s and answer slides were displayed until a key was pressed, which stopped a timer recording response time.

Response times were measured in milliseconds (msec) beginning the moment the scene was taken off of the monitor and ending with the participant's key press. Two practice scenes were provided to help orient the participant to the procedure before the experiment began.

After all 48 stimuli and 12 filler scenes were viewed, a post-survey questionnaire was given. Because some of the stimuli consisted of photographs of local traffic intersections, familiarity ratings of each scene was assessed on a 5-point rating scale anchored with (1) "Not at all familiar," (3) "Somewhat familiar," and (5) "Very familiar." Participants were also asked to indicate their overall sign preference with respect to the three sign conditions and then were asked to rate their opinion about the stimulus-presentation speed with numerical and textual anchors (1) indicating "very slow," (3) "comfortable," and (5) "very fast." The participants were then debriefed and thanked for their participation

RESULTS

Two main measures were collected from participants' responses: accuracy (proportion correct) and response time (in msec). Proportion correct scores were taken from recordings of accurate decisions to not turn right with a "No turn on red sign" present. These correct answers were recorded with a value of one and incorrect answers were recorded with the value of zero. Because response times can have large outliers, an analysis using the log transformation of the response times was also used as a dependent measure. The means and *SDs* for the three main dependent variables are shown in Table 1.

Table 1. Accuracy (in Proportion Correct), Response Time (in Msec), and Log Response Time as Function of No Turn on Red Sign Condition (N=62). Standard Deviations are Shown in Parentheses.

Sign Conditions	Proportion Correct	Mean Msec	Mean Log Msec
No-Sign	.690	2454	3.32
	(.20)	(676)	(.11)
Text-Only	.888	1996	3.21
	(.13)	(643)	(.15)
Red Circle & Text	.894	2028	3.22
	(.13)	(712)	(.14)
Prohibition Arrow and Text	.910	1881	3.19
	(.10)	(693)	(.15)

One way repeated measure analyses of variance (ANOVAs) was used to examine the data. To further examine the effects of signage within the context of the various traffic scenes, another independent group of participants ($n = 14$) provided ratings of the extent of clutter for each traffic intersection in which the manipulated signs appeared. The ratings were on a Likert-type scale from low (rating of 0) to high (rating of 8) Based on the reported perceptions of clutter, means were assigned to each scene and which enabled dividing the scenes in to those that were judged as having "low" clutter and those having "high" clutter. Two-way (2 levels of clutter X 4 sign conditions) within subjects analyses of variance were conducted for proportion correct response time and log response time to determine whether signage interacted with clutter.

Proportion correct. The four-condition one-way ANOVA indicated a significant effect of sign condition, $F(3, 183) = 39.15$, $p<.0001$. Subsequent tests indicated all three sign conditions (*M*s ranged from .89 to .91) did not differ among themselves but they were all better than the no sign condition ($M = .69$).

The two-way ANOVA indicated significant main effects of signage, $F(3, 183) = 20.66$, $p<.0001$, and clutter, $F(1, 61) = 8.44$, $p<.001$. Consistent with the one way ANOVA reported above, the main effect of signage illustrated that people committed the most errors in the no sign condition ($M = 2.3$) yet the sign conditions did not vary (*M*s ranged from 2.78 to 2.82). The main effect of clutter indicates that significantly more errors occurred in the high clutter condition ($M = 2.62$) than the low clutter condition ($M = 2.73$). The presence of the significant interaction, $F(3, 183) = 4.47$, $p<.005$. suggests that sign effectiveness varies when placed in intersections characterized by different levels of clutter Table 2 shows a trend for the Prohibition Arrow and Text to yield more accurate responses in high clutter.

Response Time: Mean Msec. With one-way ANOVA, there was a significant effect of sign, $F(3, 183) = 20.15$, $p<.0001$. Subsequent tests indicated all three sign conditions (*M*s ranged from 1881 to 2028 msec) were responded to faster than the no sign condition ($M = 2454$ msec). More importantly, two other comparisons were significant: (a) between Prohibition Arrow and Text ($M = 1881$ msec) and Text Only ($M = 1996$ msec) conditions, and (b) between Prohibition Arrow and Text and Red Circle & Text ($M = 2028$) conditions.

The two-way ANOVA indicated significant main effects sign condition, $F(3, 183) = 13.21$, $p<.0001$, and clutter, $F(1, 61) = 10.82$, $p<.002$. Participants responded slowest in the no sign condition ($M = 7383$ msec) yet the sign conditions did not vary (*M*s ranged from 5326 to 5840 msec). The main effect of clutter illustrates that response times were significantly higher in the high clutter condition ($M = 6409$ ms) than the low clutter condition ($M = 5627$ ms). As with the proportion correct analyses reported above, the presence of the significant interaction for response time further suggests that sign effectiveness varies by different levels of clutter, $F(3, 183) = $

4.46, *p*<.005. Table 2 shows the Prohibition Arrow and Text was fastest in high clutter.

Response Time: Mean Log Msec. A log transformation was applied to the raw response time data as a method to offset reduced statistical power due to positive skew resulting from a few very long response times—a commonly-used technique with response time data. Using these data in the one-way ANOVA, a significant effect was yielded, $F(3, 183)$ = 28.33, *p*<.0001. Subsequent comparisons indicated all three sign conditions (*M*s ranged from 3.19 to 3.22 log msec) were responded to faster than the no sign condition ($M = 3.32$ log msec). Again, most importantly, among the sign conditions, two other comparisons were significant (*p*<.05) between (a) Prohibition Arrow and Text ($M = 3.19$ log msec) and Red Circle & Text ($M = 3.22$), and (b) between Prohibition Arrow and Text and Text-Only ($M = 3.21$).

The two-way ANOVA indicated significant main effects of signage, $F(3, 183)=17.65$, *p*<.0001, and clutter, $F(1, 61)=$ 17.50, *p*<.001. The main effect of sign illustrated that people responded slowest in the no sign condition ($M = 3.83$ log msec). In addition, the Red Circle & Text ($M = 3.73$ log msec), and the Prohibition Arrow and Text ($M = 3.68$ log msec). The main effect of clutter illustrates that response times were significantly higher in the high clutter condition ($M = 3.76$ log msec) than the low clutter condition ($M = 3.70$ log msec). The presence of the significant interaction for response time shows that signage effectiveness varies by different levels of clutter, $F(3, 183) = 4.41$, *p*<.005. Table 2 shows a trend for the Prohibition Arrow and Text to be fastest in high clutter.

Table 2. Performance measures as a function low vs. high clutter scenes and sign condition.

Sign Conditions	Proportion Correct	Mean Msec	Mean Log Msec
Low Clutter			
No-Sign	2.24	7452	3.83
Text-Only	2.94	4667	3.63
Red Circle & Text	2.86	5462	3.70
Prohibition Arrow and Text	2.90	4925	3.65
High Clutter			
No-Sign	2.39	7315	3.83
Text-Only	2.65	6375	3.75
Red Circle & Text	2.71	6218	3.75
Prohibition Arrow and Text	2.74	5726	3.71

Post-survey questionnaire. Overall participants indicated that they were "somewhat familar" with the 12 scenes based on the mean rating was 3.02 (ranging from 2.42 to 3.69). Of the 3 signs, the Prohibition Arrow and Text sign was the most preferred; 83.9% of the participants chose it. This was followed by the Red Circle & Text at 12.9%, and finally the Text-Only sign at 3.2%. Participants indicated that the scene exposure time was somewhat fast as indicated by a mean rating of 4.18 ($SD = .56$) which lay between scale anchors rated as (3) "comfortable" and (5) "very fast."

DISCUSSION

The Prohibition Arrow and Text sign had fastest response times; confirming expectations based on previous research by Podany et al. (2004) who found higher evaluations for this sign compared to existing MUTCD signs. In addition to the response time advantage, over 80% of the participants selected it as their preferred sign—a result also similar to that of Podany et al. (2004).

Several explanations for the better findings for the Prohibition Arrow and Text sign compared to the other two signs can be made. First, it may be more conspicuous because it had a larger circle, more color, and a relatively distinctive form (compared to no graphic in the Text-Only condition and the red circle in the Red Circle & Text condition). Second a contribution to the better performance may be due to higher order comprehension factors (Wogalter, DeJoy, & Laughery, 1999). The association of the graphic might aid its recognition in complex scenes. The new sign includes the common internationally-used circle-slash prohibition symbol that is used in a broad range of "NO" or "DON'T" warning signs for various applications and hazards. The arrow accompanying it is a commonly used shape in existing directional traffic signs. Although it has these common components, it is still a novel sign (as it is unlikely any of the participants had previously seen the Prohibition Arrow and Text sign before being the study. The potential salience derived from the novelty may be another potential reason for the better performance seen with this sign design.

There were no proportion correct differences between three sign conditions in the one-way ANOVA. The lack of difference in accuracy between the signs may be due to a ceiling effect as the proportion correct scores were fairly high (around 90%) possibly indicating that viewing times were too long; future studies should consider less then 1 second viewing times. The lowered proportion correct for the No-Sign condition and lengthier response times is not unexpected and is probably a reflection of more exhaustive searching in the control condition than the sign-present conditions. A slower response time suggests that the participant needed to take extra time to make sure that no sign was there. Nevertheless, the No-Sign condition was mainly intended to provide "catch" trials to avoid participants adopting a response strategy of always indicating they could never make a right turn.

There are several other methodological limitations potentially affecting the results' interpretation. First, university students were used. This is a limitation because certain populations such as older adults and individuals with

various forms of defective vision and other maladies were not specifically tested and may differ from the university sample (Brachacki, Nicolson, & Fawcett, 1995; McPhee, Scialfa, Dennis, Ho, & Caird, 2004; O'Brian, Cole, Maddocks, & Forbes, 2002). Second, only one new sign was tested; other alternatives might also be shown to benefit performance. Also, the Prohibitive Arrow & Text differed in several ways from the other two signs; it is not possible with the present data to separate out which specific aspects of the Prohibitive Arrow & Text sign facilitated performance and preference judgments. Nevertheless, there was good control of other aspects to benefit internal validity such as with size and brightness of the signs and rotation through all of the same scenes through the use of photographic manipulation software.

Additional analyses indicated that scenes judged to be cluttered by an independent group of participants affects sign effectiveness in terms of both error production and response time (raw and log transformed). Specifically, the finding that the Prohibition Arrow and Text symbol tended to show better effectiveness than the other sign conditions for scenes rated as highly cluttered. This result suggests that a main benefit of the new sign is that it "stands out" in a scenes in which the conventional 'No Turn on Red' signs might be missed. This assertion is consistent with previous research which suggested that environmental stimuli and context affect driver performance (Meitzler, Gerhart, & Singh, 1998).

Thus, two studies (the present one and Podany et al., 2004) have shown that the Prohibition Arrow and Text sign as better than two existing MUTCD versions of the sign in terms of preference judgments and response time performance. It would seem appropriate to evaluate this sign (as well as other potential designs) for driver comprehension in more realistic conditions with respect to actual driving tasks, using simulation and postings at actual intersections. While the present study has greater external validity than Podany et al.'s (2004) ratings task, demonstrating the effect under more realistic conditions would provide stronger confirmation regarding its potential improvement over the existing MUTCD signs.

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