

Navigation Signing for Roundabouts

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ABSTRACT

The focus of this study was on navigational signage that is intended to assist motorists to anticipate the correct roundabout exit and to select an appropriate approach lane for that exit. The objective was to support recommendations on double-lane roundabout signage to the Federal Highway Administration's Manual on Uniform Traffic Control Devices Team and to the National Committee on Uniform Traffic Control Devices (NCUTCD). The Traffic Control Devices Pooled Fund Study identified the need for this research. Four currently used navigation-signing methods (Conventional, Maryland, Diagrammatic, and New York) were evaluated. In the study, volunteer participants were shown guide signs and markings in a roundabout context and asked to identify which lane they should be in and which exit they should use for a given destination. Response correctness, speed, and confidence for lane choices and leg identifications were assessed. Overall, the conventional and diagrammatic signs yielded the best performance, particularly with respect to participants' reaction time and decision confidence. The current NCUTCD markings subcommittee recommendations for lane control markings were used in the contextual stimuli presented to participants. For all navigation sign types, lane selection performance was below 70 percent correct, and not far from chance given the assumption that in the absence of other information drivers would use the left lane for left turns, the right lane for right turns, and either lane to continue straight through. Further research is recommended to determine whether the current recommended markings are sufficient for driver comprehension.

INTRODUCTION

With increasing use of modern roundabouts, issues have arisen regarding the variety of signing unique to roundabouts. An evaluation of alternatives was needed to suggest how to best communicate to drivers in advance of a multi-lane roundabout the lane they should be in for a given destination. Varied guide signing and pavement marking solutions have been suggested. A number of sign and marking combinations have been used by various jurisdictions. The TCD PFS members, who sponsored this research, perceived the need for a uniform set of guidelines. The NCUTCD Markings committee has already recommended markings for roundabouts. Therefore, this study used the NCUTCD recommended markings in combination with four advance navigation sign types to evaluate each sign type.

From a state-of-practice survey, four navigation signing alternatives were selected for evaluation. One objective of this study was to evaluate these four alternatives.

The first alternative, “Conventional”, followed the current MUTCD standard (1) used in conventional intersections. That is, two separate signs were presented: a route assembly that was followed by guide sign. The route assembly and guide sign were displayed one after the other for 2 s each. The route assembly and conventional guide signs are illustrated in FIGURE 1. The second alternative was the “Maryland” advanced guide sign. The “Maryland” type is used at many Maryland roundabouts. With this type, route shields are placed on the sign itself and horizontal lines separate sections. This type is illustrated in FIGURE 2. The third alternative was the “Diagrammatic” advance guide sign. This type is used at many roundabouts throughout the United States. It includes route shields and destination names shown in relation to a roundabout diagram. The Diagrammatic type is illustrated in FIGURE 3. The fourth alternative selected for evaluations was the “New York” advance guide sign. In this type, the left and right sides of the sign indicate the lane that motorist needs to be in for routes or destinations displayed on that side of the sign. A dashed line down the center of the slide symbolizes a lane marking. The New York type is illustrated in FIGURE 4.

Another objective of this study was to evaluate the effects of sign information load, as defined by the number of destination names and route numbers, on lane choice and exit selection. Each trial in the study presented participants with information about a 4-legged roundabout. Each leg was associated with one or two pieces of information: a destination name, a route number, or both. Thus the navigation signs varied between 3 and 6 pieces of information.

Participants were presented a destination name or route number followed by a guide sign, or guide sign and route assembly, followed by a picture of a roundabout entrance with turn restriction markings. Participants were asked to make an entrance-lane choice and an exit leg choice based on the presented stimuli. Response measures were decision accuracy, decision latency, and subjective decision confidence.

A third objective of the study was to provide a preliminary evaluation the roundabout lane control markings proposed by the NCUTCD markings subcommittee. To this end, each trial in this study presented the proposed markings with one of five turn restrictions.

METHOD

Testing was conducted in the Sign Simulation Laboratory at the Turner-Fairbank Highway Research Center in McLean, VA.

Research Design

There were five independent variables: Guide Sign Type with four levels (Conventional, Maryland, Diagrammatic, and New York); Information Items with 4 levels (3, 4, 5, or 6 items); Turn Restriction with five levels; Age Group two levels (under 65 years of age, over 65 years of age), and Gender with two levels.

Destinations were designated with a name, a route shield with cardinal heading, or both. Destination names and shields were combined factorially so that each guide sign type was presented with seven different combinations of destination name and route shield. These seven combinations are shown in TABLE 1. The total number of information items was factor of interest in this study, not comparisons of route shields versus destination names.

Five turn restrictions were factorially combined with the other two independent variables. The five options are shown in FIGURE 5.

The research design was a 4 (Navigation Sign Type) \times 2 (Age Group) \times 2 (Gender) \times 4 (Information Items) \times 5 (Turn Restriction) mixed factorial. Navigation Sign Type, Age Group, and Gender were between subject factors. Information Items and Turn Restriction were within group factors in which every participant was presented each level of those factors. There were two reasons for making Navigation Sign Type a between group factor. First, there might have been a carryover learning effect from one type to another. Second, states and localities tend to use a limited number of sign types, so that a particular driver would normally only experience one or two types of signs in their daily driving.

Participants

Sixty-four drivers participated, sixteen in each of the four Navigation Sign Type conditions. The drivers were recruited from an FHWA database of volunteers that consists of individuals who reside in the greater Washington, DC metropolitan area. There were 33 participants under 65 years of age, 17 females and 16 males, and 31 participants 65 or older, 15 females and 16 males. Gender and age groups were approximately evenly distributed among the 4 between group conditions. Each participant was paid \$30.

Procedures

Each participant experienced 90 trials with a random order of Turn Restriction, Destination, and Exit (1st, 2nd, and 3rd). The correct lane responses (i.e., left, either, or right) occurred equally often. The correct turn restriction also occurred equally often. Destination names were assigned at random subject to constraints that: (1) each destination occurred approximately equally often, (2) no more than 2 destination names per trial started with the same letter, and (3) no destination name appeared more than 3 times for the same leg. To equate destination names across conditions, all destination names had 5 letters and 2 syllables.

Participants were given 5 practice trials that were followed by 90 test trials. On individual trials, participants were first shown text, which specified either a destination name (e.g., Mason), or a route number with cardinal direction (e.g., US 460, West). Participants read the destination aloud, and then pressed a green button on the top of the touch pad, which caused, a guide sign, route assembly, or route assembly followed guide sign, to be projected onto a rear projection screen. In the Maryland, Diagrammatic, and New York conditions, the guide signs were projected for 2 s. In the conventional condition, there could be one or two projections of 2 s each. Whether there were one or two projections depended on the destination name and route number combination, shown in TABLE 1, specified for the trial. If only destination names were specified, then only a conventional guide sign was presented for 2 s. If only route numbers were specified, then only a route shield assembly was presented for 2 s. If the trial specification called for both route numbers and destination names, then the route shield assembly was presented first for 2 s and was followed by a guide sign that was also presented for 2 s.

The guide signs or route assembly presentations were followed by one of the turn restriction images shown in FIGURE 5. The turn restriction image was displayed for until the participant pressed a key to indicate which lane they should be in for their destination: left, either, or right. Both lane choice and choice latency were recorded. After making a lane choice, the participant was prompted to indicate choice confidence on a scale from 1 to 7, where 1 was labeled "Very Sure" and 7 was labeled "Not at All Sure". All responses were made on a programmable touch pad. Following the lane choice confidence response, the participant was prompted to indicate which exit leg of the roundabout was appropriate for the assigned destination. Finally, the participant was prompted to indicate confidence in the exit leg choice on the same scale used for lane choice confidence.

Each trial took about 15 seconds, and most participants completed the single session of testing in less than 45 minutes.

RESULTS

The findings for lane choice accuracy, speed, and confidence are presented first, followed by the findings for leg choice accuracy, speed, and confidence. The multivariate approach to repeated measures was used for omnibus statistical tests with a 5 percent probability level used as the criterion for reporting significant results. Interpretation

of significant differences is by visual inspection and examination of the 95 percent confidence limits about the means.

Lane Choice

Accuracy

Overall, participants selected the correct lane only 68.6 percent of the time. As can be seen, lane selection accuracy with 4 item signs was significantly better than that with 6 item signs. The only statistically reliable effect was that for the number of items on the sign, $F(1, 48) = 6.2, p < 0.05$. FIGURE 6 shows the proportion correct as a function of number of items on the signs. Error bars in the figure represent two standard errors of the mean and may be used for comparison of significant effects. In general, any mean that is outside the area enclosed by the error bars of another mean is significantly different from that mean. Conversely, means that fall within the range of the error bars of another mean are not significantly different from that other mean.

With three equally probable responses, chance performance in lane choice would be 33.3 percent. The mean observed response of 68.6 was well above chance. However, if participants used only the simple heuristic of choosing the left lane for left turn movements, the right lane for right turn movements, and either lane for straight through movements, then performance would have been 65 percent correct. The 95 percent confidence limits for the overall mean were from 65.2 percent to 71.8 percent. The finding that correct lane selection was only marginally better than what would have been achieved using a simple heuristic suggests that most participants did not understand the importance of the turn restriction arrows, and that most New York group participants did not understand the importance of the left-right organization of information on that sign type.

Speed

FIGURE 7 shows the mean response times for the lane choice response. To avoid cluttering the figure, error bars that represent two standard errors have been placed only around the means for the diagrammatic signs. The variability of the remaining means was quite similar. The older and younger groups responded differently to the sign types, as reflected in the significant 3-way interaction of sign type, age group, and number of items, $F(9, 144) = 3.7, p < 0.01$. The younger group responded more quickly than the older group to the Conventional and Maryland type signs. Both age groups were slower in responding to the New York and Maryland type signs. The slowest times of the younger group were to the Maryland type with 3 or 4 items. The older group responded most slowly to the New York sign when it had 5 or 6 items. Overall, responses to the New York and Maryland type signs were slower than those to the Conventional and Diagrammatic signs. This main effect of Navigation Sign Type, $F(3, 48) = 3.1, p < 0.05$, was not negated by the 3-way interaction.

Confidence

As can be seen in FIGURE 8, where lower numbers indicate higher confidence, participants were fairly confident of their lane selection choices despite the finding that they were only correct 68.5 percent of the time. Participants were somewhat less confident with the New York and Maryland signs than they were with the Conventional and Diagrammatic signs. The difference resulted in a significant Navigation Sign Type effect, $F(3, 48) = 3.8, p < 0.05$.

Leg Choice

Accuracy

FIGURE 9 shows exit leg selection accuracy as a function of sign type, age group, and the number of items of information on the sign. As a result of the notably poor performance with the New York type sign, the sign type effect was statistically significant, $F(3, 48) = 43.1, p < 0.001$. The finding that leg identification was poorer with the New York sign is not surprising given that the New York sign provides no reliable clues for leg selection. Overall, the younger group was more accurate than the older group, which resulted in a statistically reliable age effect, $F(1, 48) = 8.0, p < 0.01$. The proportion correct tended to decrease with an increase in the number of items on the sign, $F(3, 48) = 2.8, p < 0.05$.

Speed

Only the older group gave slower leg choice responses as the number of information items increased, and then only for the New York type sign. This pattern, shown in FIGURE 10, resulted in a 3-way interaction of Navigation Sign Type, Age Group, and Number of Items, $F(9, 144) = 3.7, p < 0.001$.

Confidence

Consistent with the higher error rate for leg selection with the New York type sign, participants in the New York group provided the lowest leg choice confidence ratings. Mean confidence ratings as a function of sign type and number of items are shown in FIGURE 11. The Maryland group was more confident of its lane selection than was the New York group, but still less confident in their leg choices than were either the Conventional sign group or the Diagrammatic sign group. The latter two groups exhibited nearly full confidence in their decisions. The sign type effect was significant, $F(3, 48) = 11.4, p < 0.001$. There was a slight, but nonetheless statistically significant, effect of number of items. Confidence decreased with an increasing number of items, $F(3, 144) = 3.9, p < 0.05$.

DISCUSSION

Participants did not appear to use either the turn restriction markings proposed by the NCUTCD, or the lane choice information available on the New York guide signs. Overall, participants chose the correct lane only 68.5 percent of the time, a performance level that would be unacceptable if observed at actual intersections. This level of performance should raise concerns. It is possible that the low level of performance in lane choice was an artifact of the experimental design: that is, it is possible that participants didn't process the roundabout picture with turn restriction markings because of some experiment specific context. Participants were not told that the roundabout pictures contained turn restriction arrows, or what the arrows meant in a roundabout context. Indeed, some participants admitted in the post-experiment debriefing that they did not notice the arrows. Others commented that they ignored the arrows because they were obviously wrong: that drivers should not be directed clockwise through a roundabout.

In designing the experiment it was assumed that drivers understand the meaning of turn restriction arrows at intersections, and that no explanation of the arrows would be necessary. Because this assumption proved wrong, two questions should be considered: (1) Do US drivers consider roundabouts to be intersections? (2) Are standard turn restriction arrows understood by US drivers in the roundabout context? The results of this experiment cannot answer these questions, but they strongly suggest that these questions should be addressed.

The New York type sign was not well understood by participants in this experiment. Lane choice decisions were not better than with the other signs, even though the New York sign contains all necessary lane choice information, and the other signs do not provide fully sufficient information. The test was not conducted in New York, and it is unlikely that many of the participants, who were recruited in the greater DC metropolitan area, had experience with this sign type. It is possible that lane choice would have been better if the New York sign had explained to the participants before testing was begun.

For lane choice, the New York and Maryland signs responses were significantly longer than the Conventional and Diagrammatic signs. Because response time was assumed to be related to sign processing time, this finding implies that the New York and Maryland signs require more time to process than the Conventional and Diagrammatic signs. Theoretically, the greater processing time implies greater demands on a driver's attention and, as a result, fewer attention resources would be available to process other roadway and traffic information.

Visual demand was not directly measured in this experiment, as responses were not made until the signs were removed from the display and the roundabout picture with turn markings was displayed. Visual demand is more directly related to eyes-off-road time than number of items, as the organization of information on a sign can be just as important as the amount of information on the sign. As information was defined in this study, all the sign types had the same amount of information, and so all differences between sign types must be attributed to the organization of the information. The conventional sign type is the only one that potentially spreads information across two signs: the route number assembly and the conventional guide sign. An important consideration for driver visual attention is whether eyes-off-road time varies when the same information is spread across two signs. Because the conventional and diagrammatic types yielded the best performance in this study, and because eye glance demands can be an important safety consideration, it is recommended that glance behavior, i.e., number and duration of glances, be assessed for these two sign types.

For exit leg identification, participants performed significantly worse with the New York sign type when compared to the Conventional and Diagrammatic signs. Additionally, the Conventional and Diagrammatic signs were given higher confidence ratings compared to the Maryland and New York type signs. Taken together, the findings from the laboratory experiment suggest that the Conventional and Diagrammatic guide signs are better understood and processed more than the Maryland and New York guide signs. From an agency perspective, one of the advantages of the conventional guide sign is that it does not take as much space to portray information as the Diagrammatic sign does. However, it is important to note that Diagrammatic signs might be more likely to provide the needed information at locations with geometry that varies from a standard four-way approach. For example, three-way and five-way roundabouts as well as roundabouts where the approaches intersect at odd angles might benefit from the use of a Diagrammatic sign. The present study only presented an orthogonal four-approach intersection, so it cannot address the relative benefits of diagrammatic versus conventional guide signs for other geometries.

The present study provides no explanation for why the Maryland and New York Guide signs yield lower performance, compared to the conventional and diagrammatic guide signs. The Maryland sign is similar in most respects to the conventional sign, differing only on the added lines to separate information for different exits, and the inclusion of route shields on the same sign instead of on a separate assembly in the conventional case. It should be noted that when only route shields or only destination names were provided, a subset of trials with only 3 items on the signs, the Maryland and conventional sign performance did not differ on any performance measures. In these cases, 3 items, all route shields or all destination names, performance with the New York sign was also equivalent across all performance measures.

CONCLUSIONS

When route shields and destination names are combined on the same sign or set of signs, conventional or diagrammatic signs are recommended.

Lane choices in the laboratory study appeared to be unaffected by the turn restriction markings that were displayed just before participants were to respond. Either the participants did not understand the meaning of the turn restriction markings in the roundabout context, or they did not notice the markings. Given that the participants were specifically told that the purpose of the study was to identify the best way to indicate which lane should be used, it would be surprising that they would intentionally ignore turn restriction markings. However, it is possible that the laboratory task did not provide sufficient context for the turn restriction markings, and that in a dynamic driving task the markings would be processed and understood. Further evaluation of turn restriction markings in a dynamic roundabout environment is recommended.

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TABLE 1 Combinations of Destination Names and Route Shields

Number of Names	Number of Route Shields	Items of Information
0	3	3
1	3	4
2	3	5
3	3	6
3	2	5
3	1	4
3	0	3



FIGURE 1 Conventional roundabout route assembly (left) and guide sign (right).



FIGURE 2 Maryland roundabout guide sign.



FIGURE 3 Diagrammatic roundabout guide sign.



FIGURE 4 New York roundabout guide sign.

Left lane left only



Left lane left only, no left from right lane



No right from left lane, no left from right lane



No right from left lane, right lane right only



Right lane right only



FIGURE 5 Five pavement marking turn restrictions.

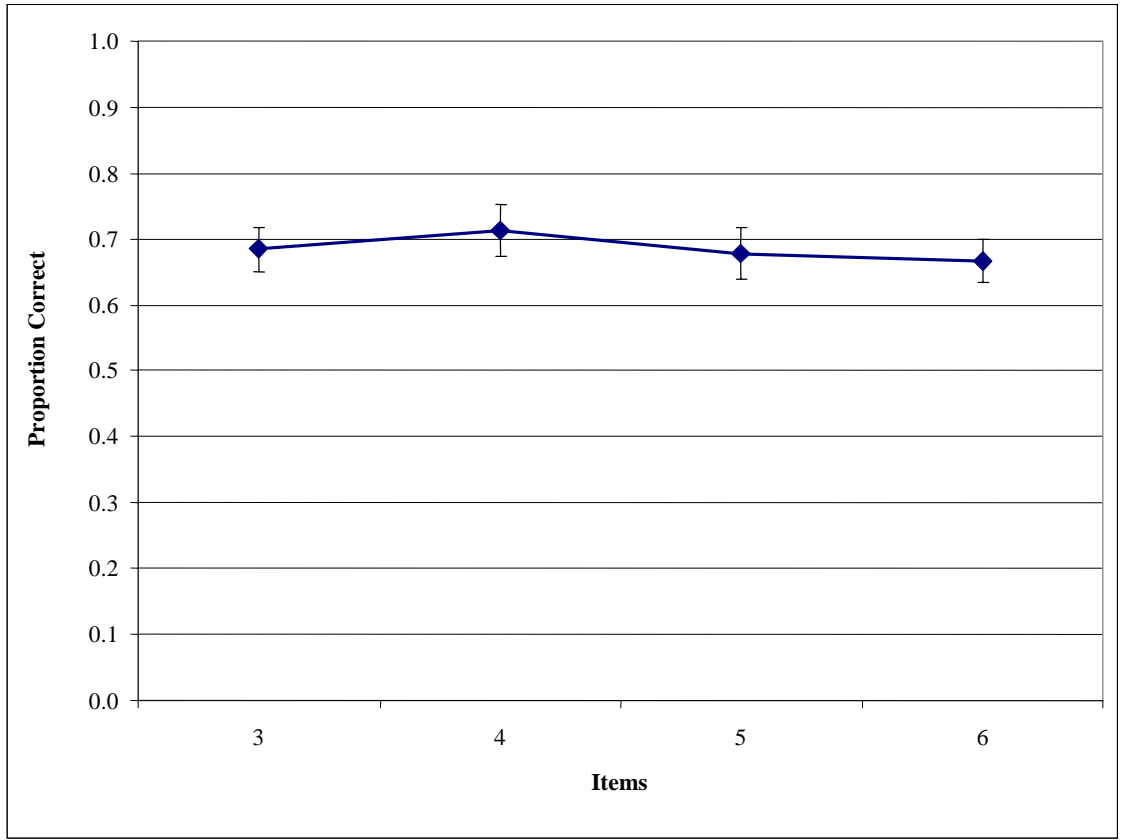


FIGURE 6 Lane choice accuracy as a function of the number of text and route shield items.

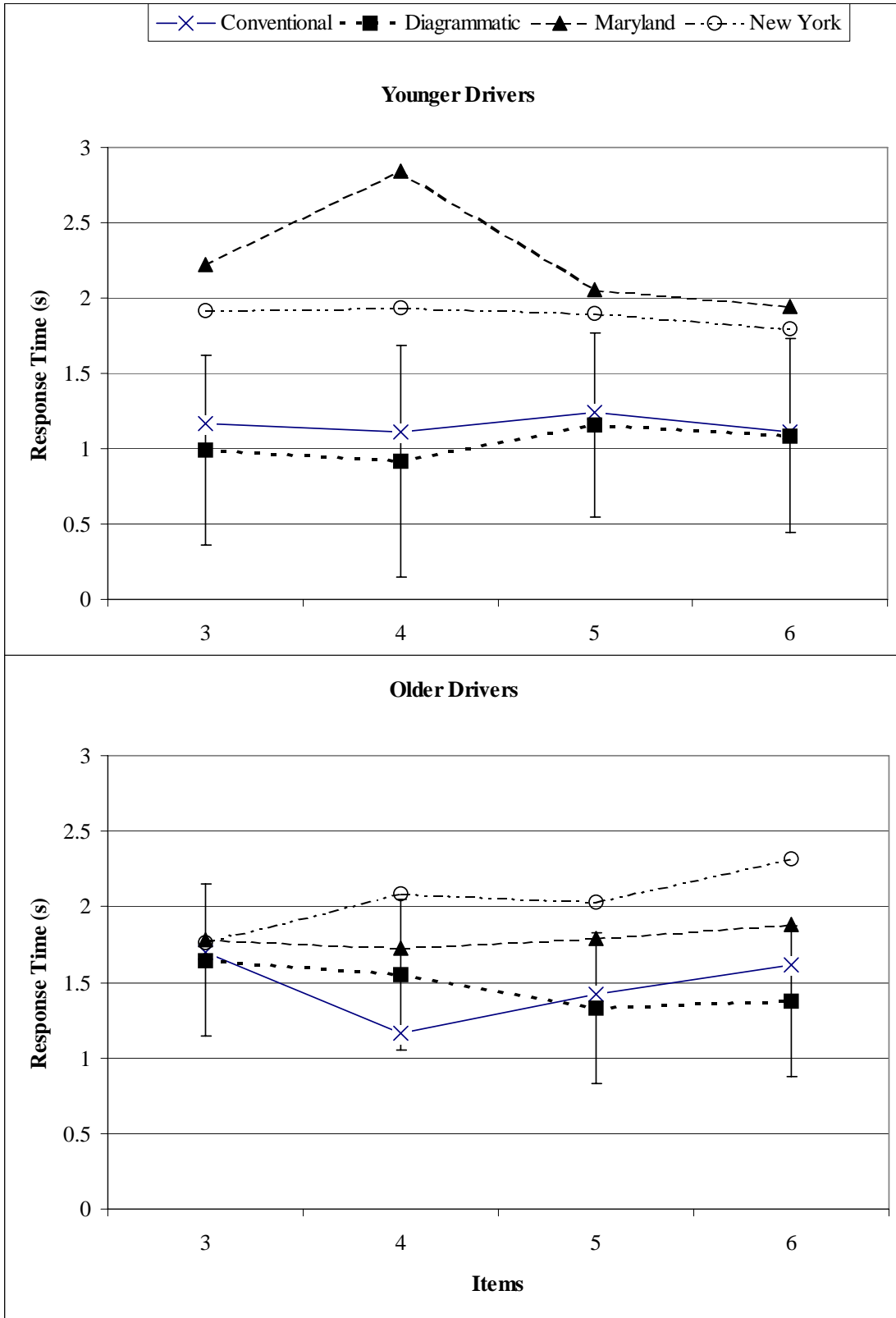


FIGURE 7 Response times, in seconds, for lane choice decision as a function of navigation sign type, age group, and number of information items.

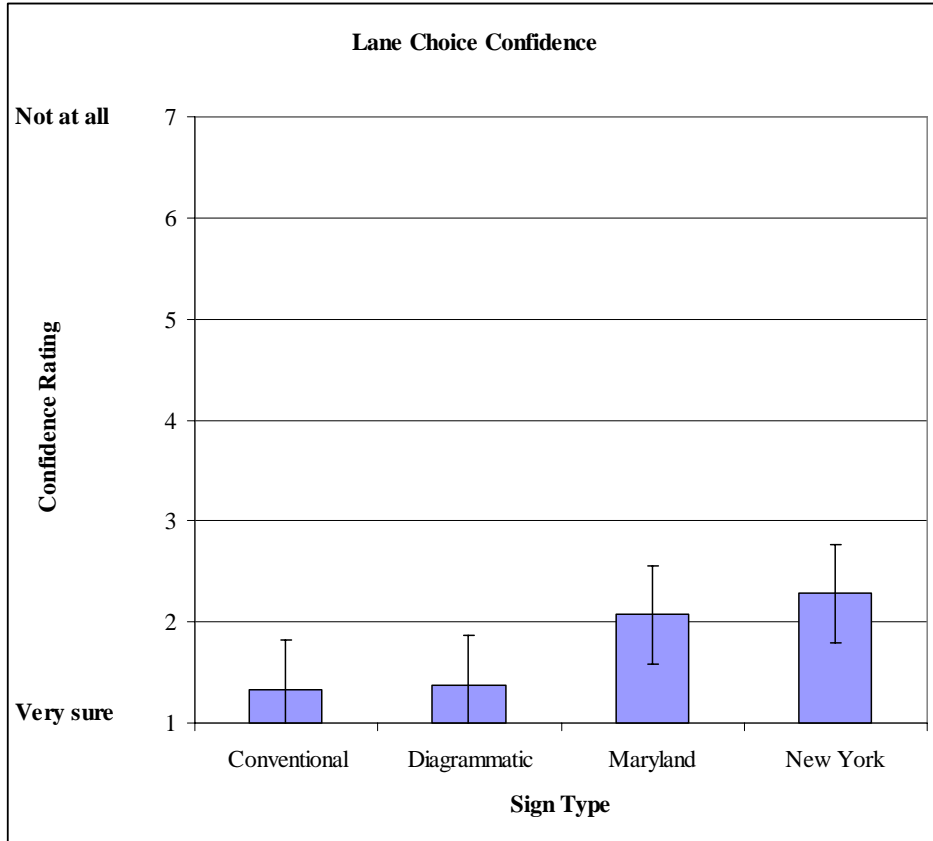


FIGURE 8 Mean lane choice confidence rating by sign type.

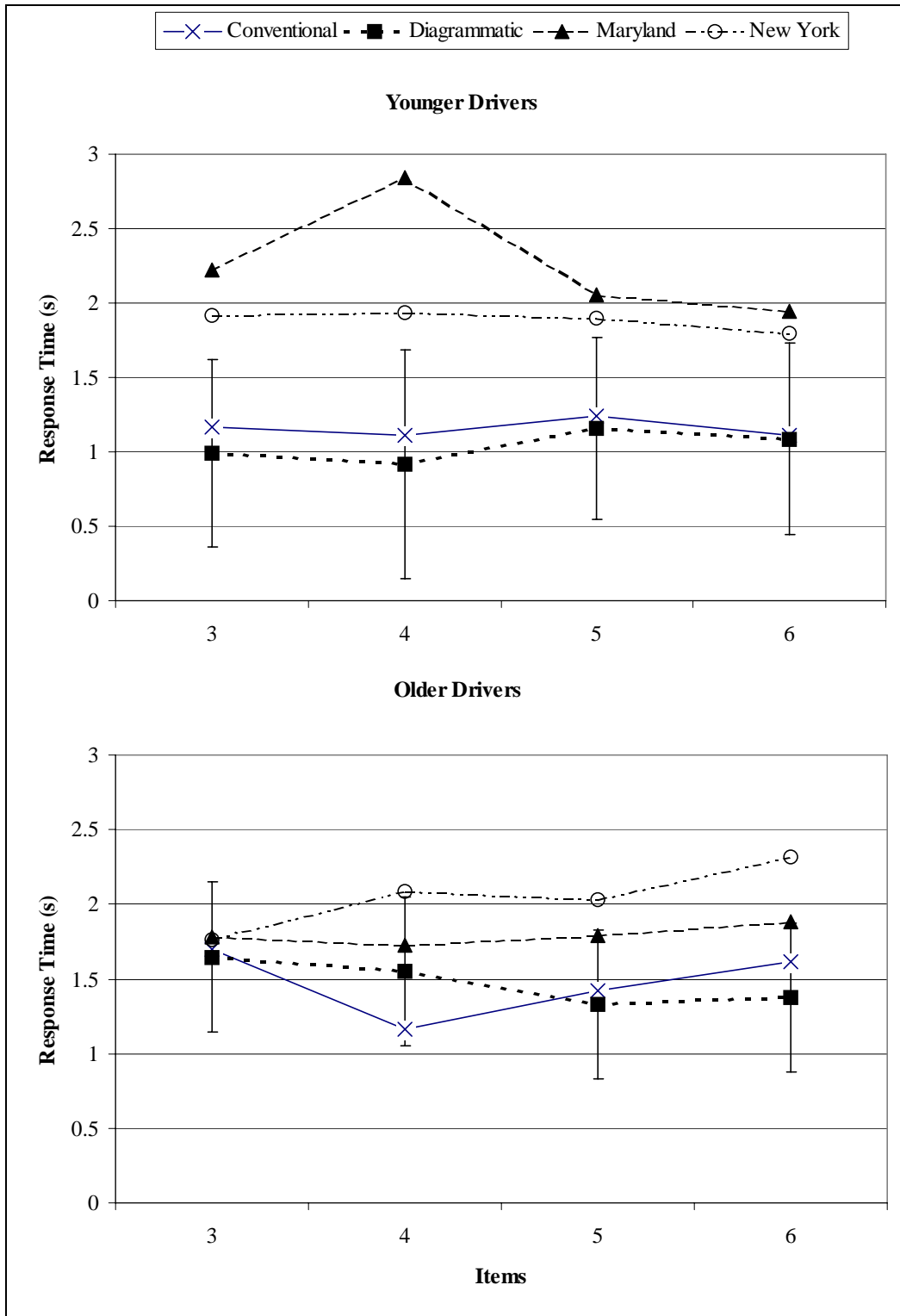


FIGURE 9 Mean proportion of correct exit leg selections as a function of sign type, age group, and items.

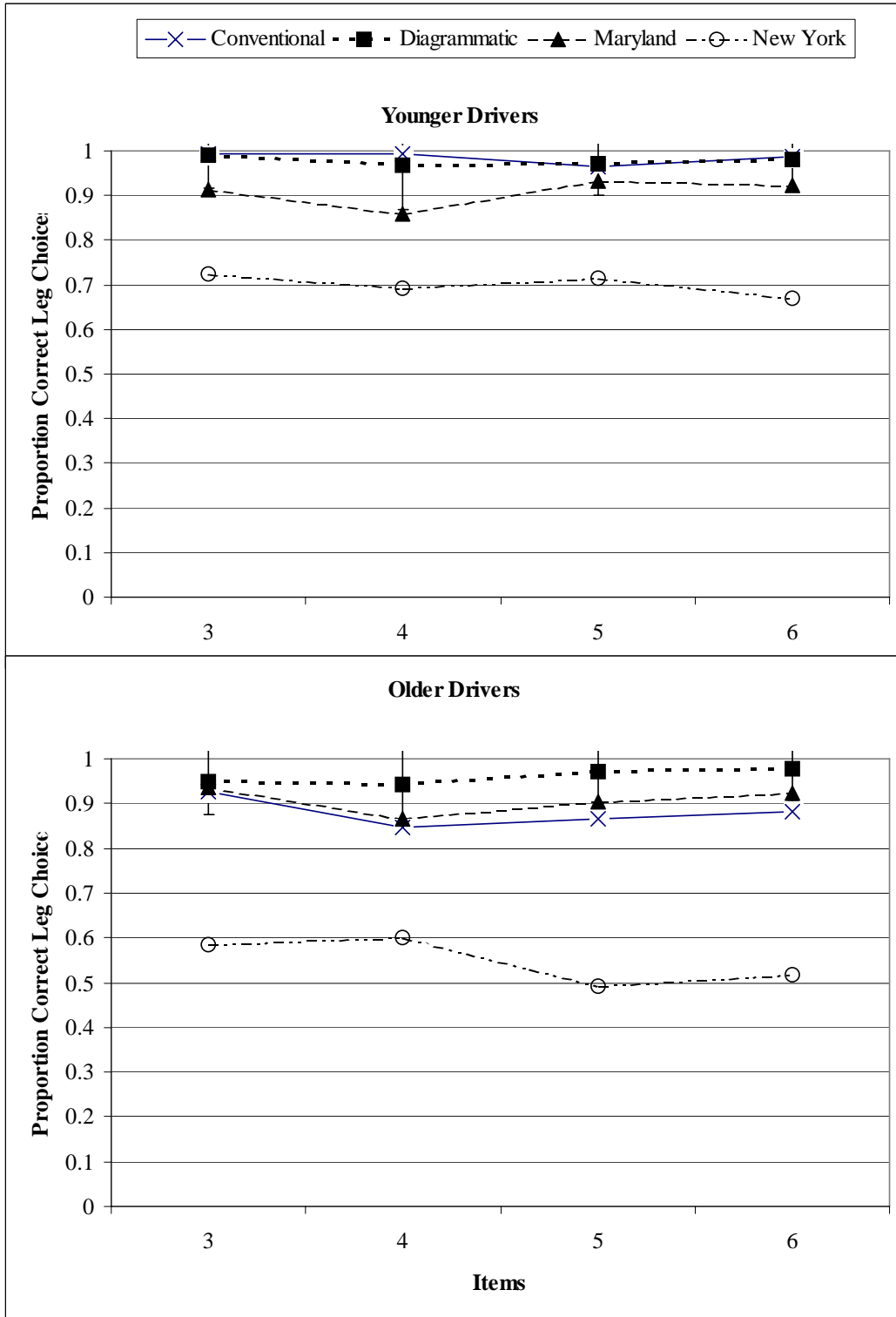


FIGURE 10 Mean leg choice reaction time by sign type and number of items.

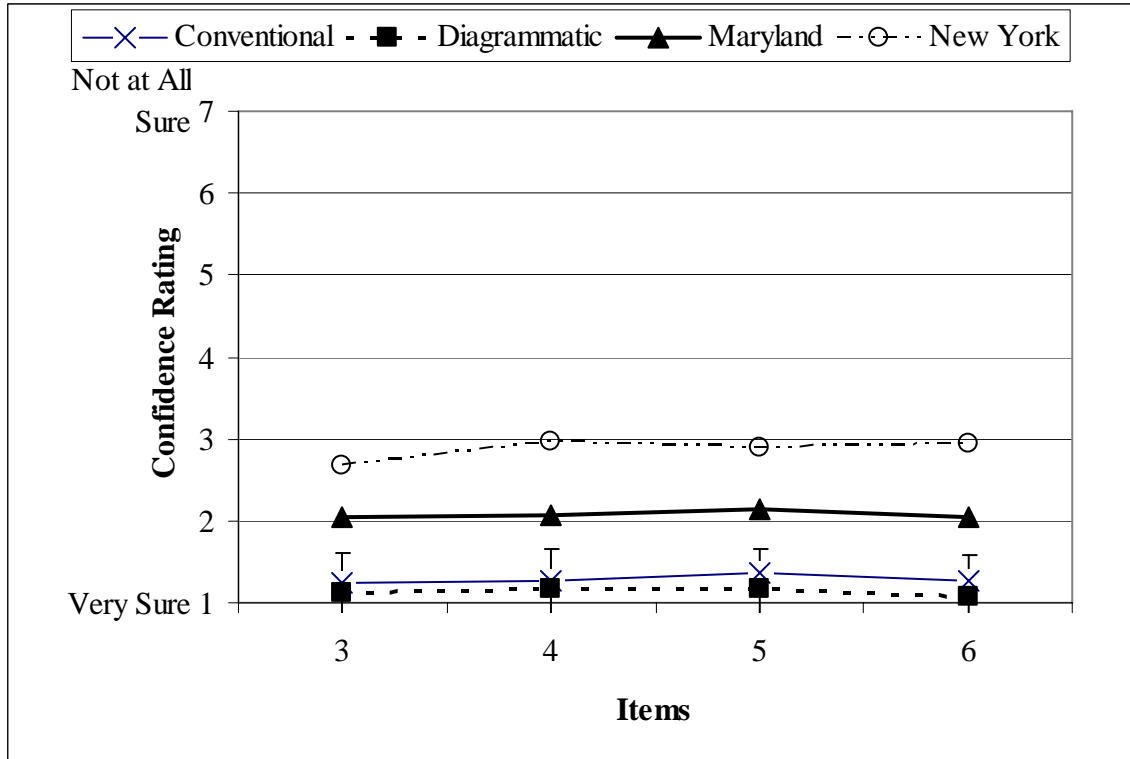


FIGURE 11 Mean Leg choice confidence rating by sign type and number of items of information.