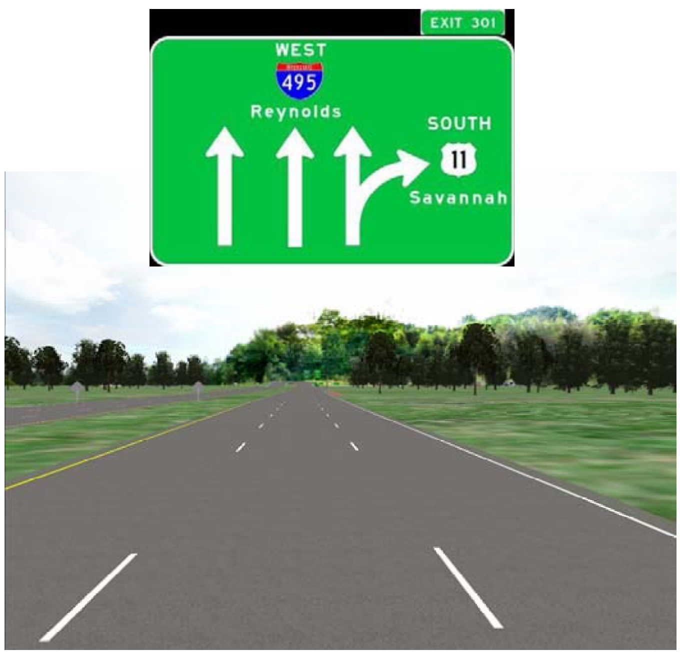
Traffic Control Devices Pooled Fund Study

Diagrammatic Freeway Guide Sign Design

Final Report

May 2008



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This research project was sponsored by the Traffic Control Devices Pooled Fund Study, TPF-5(065). Members of the Pooled Fund Study Panel are as follows:

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The objective of the Traffic Control Devices Pooled Fund Study (TCD PFS) is to assemble a group composed of State and local agencies, appropriate organizations and the FHWA to 1) establish a systematic procedure to select, test and evaluate approaches to novel TCD concepts as well as incorporation of results into the MUTCD; 2) select novel TCD approaches to test and evaluate; 3) determine methods of evaluation for novel TCD approaches; 4) initiate and monitor projects intended to address evaluation of the novel TCDs; 5) disseminate results; and 6) assist MUTCD incorporation and implementation of results.

To join the TCD PFS, or for more information about the TCD PFS
Contact Tom Granda at (202) 493-3365 or contact Scott Wainwright at (202) 366-0857
Visit www.pooledfund.org and search for study # TPF-5(065).

EXECUTIVE SUMMARY

The Traffic Control Devices Pooled Fund Study (TCD PFS) focuses on a systematic evaluation of novel TCDs, employing a consistent process that addresses human factors and operations issues for each TCD idea. As part of the PFS effort, the FHWA Human Centered Systems Team evaluated freeway guide signs' efficiency in directing drivers to the appropriate lane(s) that could be used to reach their destination. Forty-eight drivers (with equal proportions of male and female drivers and older and younger drivers) viewed forty-nine signs and indicated when they were "100% confident" that they could identify all lane(s) that could be used to reach their destination. The signs included in the study consisted of five different types, which are referred to as: (1) Standard, (2) Modified, (3) Enhanced, (4) Enhanced Modified, and (5) Arrow Per Lane.

The Standard sign followed the 2003 MUTCD guidance for freeway guides signs at lane splits. The Modified signs followed the same guidance but included Exit Only placards where appropriate. The Enhanced signs followed the Manual of Uniform Traffic Control Devices (MUTCD) guidance but had wider dashed lines and wider arrowheads. The Enhanced Modified Signs were similar to the Enhanced signs, but included Exit Only placards when appropriate. The Arrow Per Lane signs used upward pointing arrows centered over each lane to indicate movements appropriate for that lane.

In addition to varying the sign types on a trial by trial basis, the parameters were the direction of exits (left and right), the number of exiting lanes, and the presence of option lanes. Participants viewed the signs at the Highway Sign Design and Research Facility at the FHWA Turner-Fairbank Highway Research Center. As the signs were presented to participants, they indicated by a button press when they were sure of which lane(s) could be used to get to their destination. The distance to each sign when the choice was made (decision sight distance) and the correctness of each decision were recorded.

In terms of correct lane choices, the Arrow Per Lane signs yielded significantly better performance for older drivers than the other types. This result was especially evident for scenarios without the presence of option lanes. In all conditions, the performance of younger participants was significantly better than that of the older participants. The younger group was correct 86% of time with their lane choices overall, compared to older participants who were correct only 69% of the time. Younger participants also showed significantly longer simulated decision sight distances than older participants, averaging approximately 24% longer distances for all sign types.

These findings indicate that the Arrow Per Lane sign type is appropriate for all drivers and is especially beneficial for older drivers. In the present experiment the signs were presented without the surrounding roadway context. Because the Arrow Per Lane sign has arrows that are intended to provide additional meaning by being centered over the lanes to which they apply, additional research in which the highway context is provided may show that the present study underestimates the benefit of these signs relative to the other types. In addition, the present study did not employ Exit Only placards on the Arrow Per Lane signs. The additional benefit to comprehension that these placards may provide should be evaluated.

ACKNOWLEDGEMENTS

The study team would like to thank a number of individuals and organizations without whom this study would not have been possible. First, Scott Wainwright of FHWA was instrumental in guiding the research plans and stimuli development. Jonathan Upchurch also helped by providing valuable comments regarding the design.

A number of members of Science Applications International Corporation were also very helpful. Dana Duke performed all the programming necessary to conduct the study; Jason Kennedy and Tiana Petit were also helped in designing the study, recruiting participants, and conducting the study.

DISCLAIMER

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INTRODUCTION

PROBLEM STATEMENT

Providing highway navigational information that is clearly understood, timely, and easy to read is critical to ensuring that road users are able to safely navigate to their destinations. Clear navigational information is even more critical for older road users whose capabilities may be diminished relative to the younger drivers. Highway driving for older drivers can be challenging because of their generally longer reaction times and reduced visual capabilities (Staplin, et al., 2001). These challenges, coupled with the extra demands imposed by the tactical decisions of navigating – including lane-changing, merging, and exiting on high speed highways – suggested to Staplin et al. that highway guide signs to improve older driver performance on roadways can be achieved by increasing decision sight distance.

Improved highway guide signing is critical is on highways with lane splits, lane drops at exits, shared exit lanes, and multiple highway exits. Recommendations in the Highway Design Handbook for Older Drivers and Pedestrians (Staplin, et al.,2001) suggested specific changes to the MUTCD design standard for diagrammatic signs (Federal Highway Administration, 2003). These recommendations suggest that freeway guide signs should utilize upward-pointing arrows (1 per lane) to show both the number and direction of lanes for particular highway geometric conditions (e.g., exits, lane splits, lane drops). The design recommendations differ from the current design of a single arrow shaft with bifurcating arrow heads and dashed lane lines within the shaft (Federal Highway Administration, 2003). The Staplin, et al, recommendations, which are hereafter referred to as Arrow Per Lane (APL) were based primarily on a series of opinion surveys of highway safety experts and designers – not on empirical research. Performing an empirical evaluation of design recommendations was one purpose the present study.

Previous research suggested the main advantage of diagrammatic signs is their ability to display lane choice interchange configurations (Taylor and McGee, 1973). However, Gordon (1972) reported that conventional signs produced fewer lane-placement and exit lane errors than diagrammatic signs. Both Taylor and McGee and Gordon found that conventional signs yielded shorter response times than diagrammatic signs, except in the situation where a diagrammatic sign depicted a single arrow or forked arrow for each lane at the interchange. Zajkowski and Nees (1976) also found longer reaction times to diagrammatic signs although this result may have been due to the diagrammatic signs containing more information than the conventional signs. Mast, Chernisky, and Hooper (1972) also found that drivers may require more time to read and interpret information on the diagrammatic signs than on conventional signs and that the interpretation time may increase with the complexity of the graphic components.

However, Brackett, Huchingson, Trout, and Womack (1992) conducted a survey of 662 drivers in 3 age groups (under 25, 25-34, and 55 and older) in which they found better comprehension of a diagrammatic sign. Their modified diagrammatic signs, which provided separate arrows for each lane, were better understood than a conventional MUTCD. Their diagrammatic sign yielded better understanding of which lanes were exit lanes and whether adjacent lanes could be used either to exit or to continue through on the mainline (i.e., were option lanes).

Focus group discussions with older drivers (Knoblauch, Nitzburg, and Seifert, 1997) indicated that older drivers prefer large, lighted overhead signs with arrows that indicate lanes for specific destinations, especially if they are approaching a fork in the road.

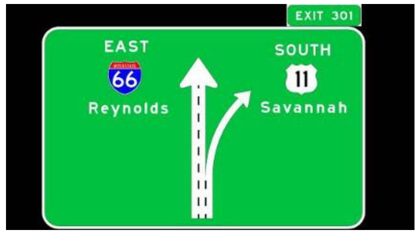
RATIONALE

This study was conducted to obtain additional empirical data with which to assess the effectiveness of the APL guide signs as they compare to various conventional guide sign alternatives. Two measurers of effectiveness were obtained: decision sight distance and sign comprehension. To ensure that the findings applied to older drivers, half of the participants were seniors (age 75 and older).

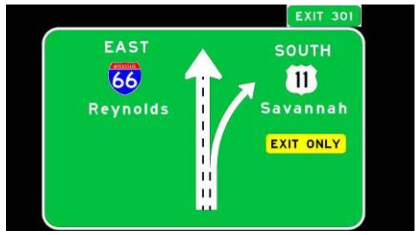
RESEARCH OBJECTIVES

The research objective was a comparison of the upward-pointing Arrow Per Lane design (i.e., the APL) against the following conventional alternatives:

- The 1993 MUTCD standard
- An Enhanced standard sign that uses the “Exit Only” message for dropped lanes
- Modified 1993 MUTCD standard signs using wider lanes arrow heads, and bolder lane lines
- Enhanced Modified MUTCD standard sign (with the “Exit Only” message) using wider lanes, arrow heads, and bolder lane lines

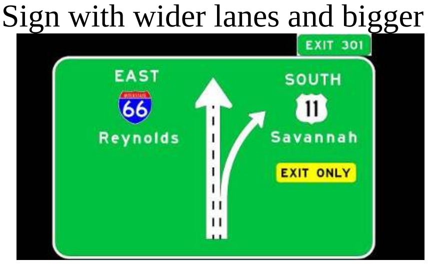


Current Standard

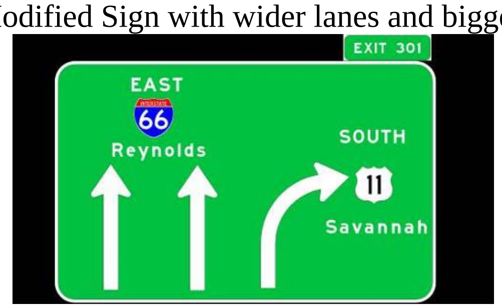


Enhanced Sign (“Exit Only”)

Modified Sign with wider lanes and bigger arrowhead



Enhanced Modified Sign with wider lanes and bigger arrowhead



Arrow Per Lane

Figure 1. Examples of Sign Types (3 lanes, single right exit, no option lane) Tested in the Experiment

APPROACH

The study was conducted at the FHWA Turner-Fairbank Highway Research Center in Highway Sign Design and Research Facility . Guide signs were rear projected onto a screen. The presentation was computer-controlled. The guide sign stimuli were developed using SignCad® and edited to incorporate the enhancements (increased lane width, arrowhead size, etc.) as necessary. The signs were then converted to 35mm slides. Each sign was designed to a simulated size of 16 feet wide by 10 feet high and used the FHWA E-series font with 12-inch text.

For the experiment, each trial began with the sign displayed at size that approximated how it would appear from 600 ft away. The size of the sign on the screen then gradually expanded to simulate how it would appear if the participant approached it at a speed of 50 mph. The size of the signs on the screen was controlled by varying the voltage to a servomotor, which in turn controlled the zoom lens on the projector.

As each sign approached, participants were to decide when they were "100% sure" of the lane(s) they could be in to reach their destination. The instructions to participants were:

> *You will be shown a number of slides that depict a situation on a highway, similar to I-495, or the Beltway, in the Washington area. Each slide will be a picture of a guide sign with information to direct you to your destination. For purposes of this experiment, your destination will always be "SAVANNAH." Your task is to tell us which lane or lanes would allow you to get to Savannah. On some signs you will exit and on some you will stay on the main road.*
>
> *When deciding on the lanes, remember that you should pick the lane or lanes that you could be in to get to Savannah, not necessarily just the lane (or lanes) you yourself would choose.*
>
> *As each new slide is shown, the sign will begin as a very small image (similar to how it would appear if it were far away on a highway) and then we will "zoom" the picture so it gets larger (and appears to be getting closer to you). Using the small panel on the table in front of you, we would like you to press the button (or buttons) that correspond to the lane (or lanes) you could be in so you can be in a correct lane to get to Savannah. If there is more than one lane that would allow you to get to Savannah, please press the buttons for all those lanes. Please press the button(s) after you are able to read the sign and you are 100% sure which lane(s) you could be in to get to Savannah. As soon as you press a button, the sign will disappear and the screen will darken.*
>
> *Do you have any questions?*
>
> *If not, we will start with a few practice slides to make you comfortable with how the signs look, with the keypad, and the general procedures of the experiment.*

Please feel free to ask me any questions at any time. If you're ready, we'll start.

At this point the room lights were dimmed and the session began. Participants were allowed as many practice trials as were needed (typically just two) and their responses were monitored to ensure they were correctly following instructions, and were choosing multiple lanes when appropriate. The practice signs, while similar to the experimental signs, did not replicate the stimuli used during the experiment.

An example of the key pad designed for the experiment is depicted in Figure 2. The keypad showed a static picture of a roadway to provide participants with a scene and give them contextual cues for the type of roadway on which they were "driving." The picture also provided labels for the lane designations. The pictures (and the appropriate number of response buttons) were displayed; one for 6-lane roadways and one for the 8-lane roadways. It is important to note that this picture did not fully simulate an actual highway nor were the signs displayed above the lanes on the highway scene. The pictures were used only to provide a context for the lane choices. Half the participants were tested with 6-lane highways first, followed by 8 lane highways, and the other half were tested with 8-lane highways first. The picture on the keyboard was changed when participants changed between highway types.

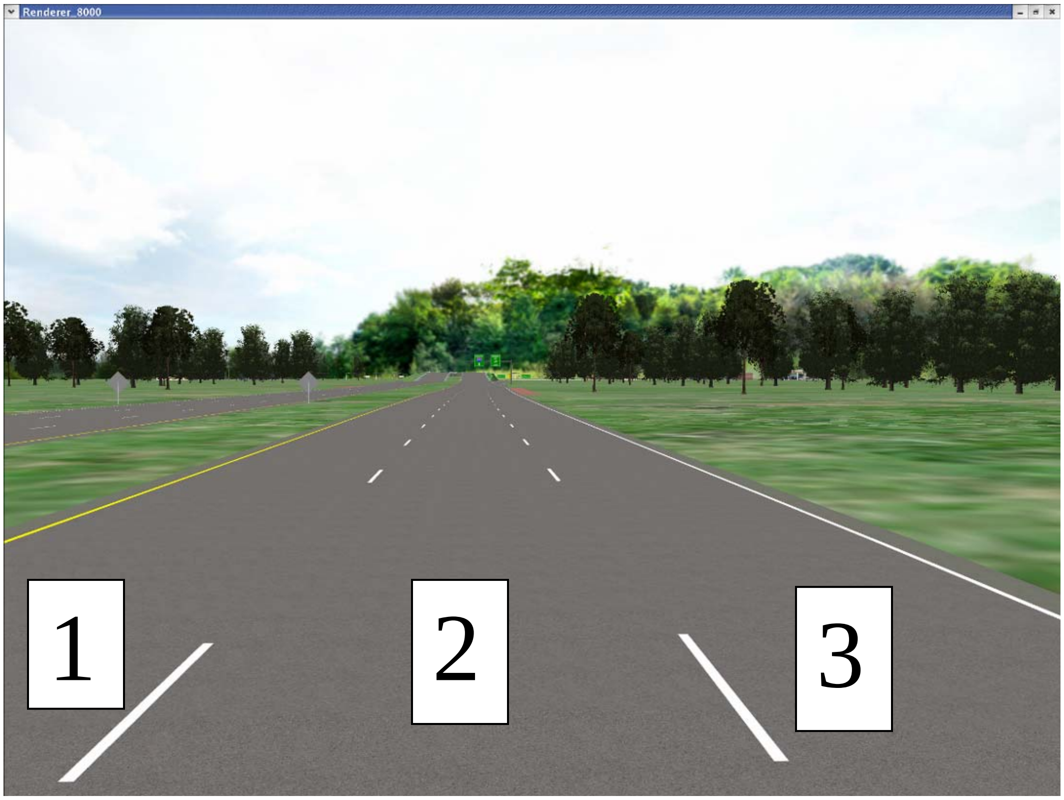


Figure 2. Example of Response Pad Screen Depicting 6-lane Roadway (3 lanes in each direction) with Lane Designations

MEASURES OF EFFECTIVENESS

The two dependent measures were:

- Simulated decision sight distance
- Correctness of lane choice

Participants were instructed to begin selecting appropriate lanes as soon as they knew which lane(s) could get them to their destination. The simulated distance at which the participants made their first lane choice is referred to as the decision sight distance.

The method used to calculate decision sight distance was based on the concept of similar triangles, as shown in Figure 3. Actual height was the real world height of the pictured sign, while presentation height was the measured dimension of the projected image on the screen. Viewing distance was the distance between the participant and the screen (7 feet). Using these known values the actual distance at which a real world sign would have supported a lane decision was calculated.

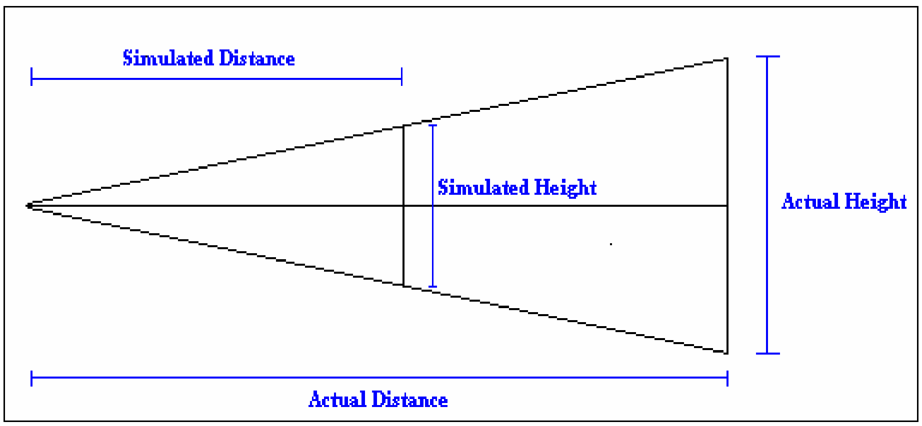


Figure 3. Depiction of Simulated to Actual Sign Size Relationship

The similar triangles produced in the figure gives the relationship for determining the actual distance of the sign as:

$$\frac{\textit{Viewing Distance}}{\textit{Actual Distance}} = \frac{\textit{Presentation Height}}{\textit{Actual Height}},$$

which can be converted to:

$$\textit{Actual Distance} = \frac{\textit{Viewing Distance X Actual Height}}{\textit{Presentation Height}}$$

Participants' lane choices were scored as correct only if all possible choices were selected.

EXPERIMENTAL DESIGN

Experimental Conditions

The experimental conditions partially addressed the following factors:

- Types of highways
  - 6 lane (3 lanes in each direction)
  - 8 lane (4 lanes in each direction)
- Number of exit lanes
  - single exit lane
  - multiple exit lanes
- Exit directions
  - right exit
  - left exit
- Presence of option lane
  - option lane
  - no option lane
- Sign Type
  - current standard sign
  - current standard with "Exit Only" message
  - enhanced standard sign
  - enhanced standard sign with "Exit Only" message
  - arrow per lane

Because of resource constraints, not all factors were crossed with all other factors (e.g., Enhanced Exit Only placards were not tested for multiple lane exits).

Each participant viewed the same 40 signs. To minimize order effects, four different randomized sets of the signs were constructed. Each participant was randomly assigned one of the presentation orders.

Participants

Forty-eight participants were recruited; with an equal number of men and women as well as younger (under 75 years old) and older drivers (over 74 years old). Table 1 summarizes the sample characteristics. All participants were required to have a current driver's license and have at least 20/40 visual acuity (with correction).

Table 1. Participant Characteristics

	Male	Female	Total	Mean Age	Age Range
Younger	12	12	24	33.0	21 - 66
Older	12	12	24	79.3	76 - 84
Total	24	24	48		

RESULTS

DECISION SIGHT DISTANCE

Decision sight distance was computed only for trials on which participant responses were scored as correct, i.e., only if all available lanes were identified. Shorter decision sight distances indicate that participants were exposed to the signs longer and were closer to the signs when they made their lane choice decision. The methodology used did not provide a way to distinguish whether time, distance, or both were responsible for decision sight distance outcomes.

As shown in Figure 4, for older drivers mean decision sight distance, averaged across all signs, was significantly shorter than for younger drivers; $F(1, 2252) = 362$, $p < 0.001$ (error bars depict the 95% confidence interval). This finding indicated that older drivers required more time (and/or a shorter sight distance) to decide which lane(s) they could be in to get to their destination. Overall, the older drivers' mean decision sight distance was 24% shorter than the younger drivers.

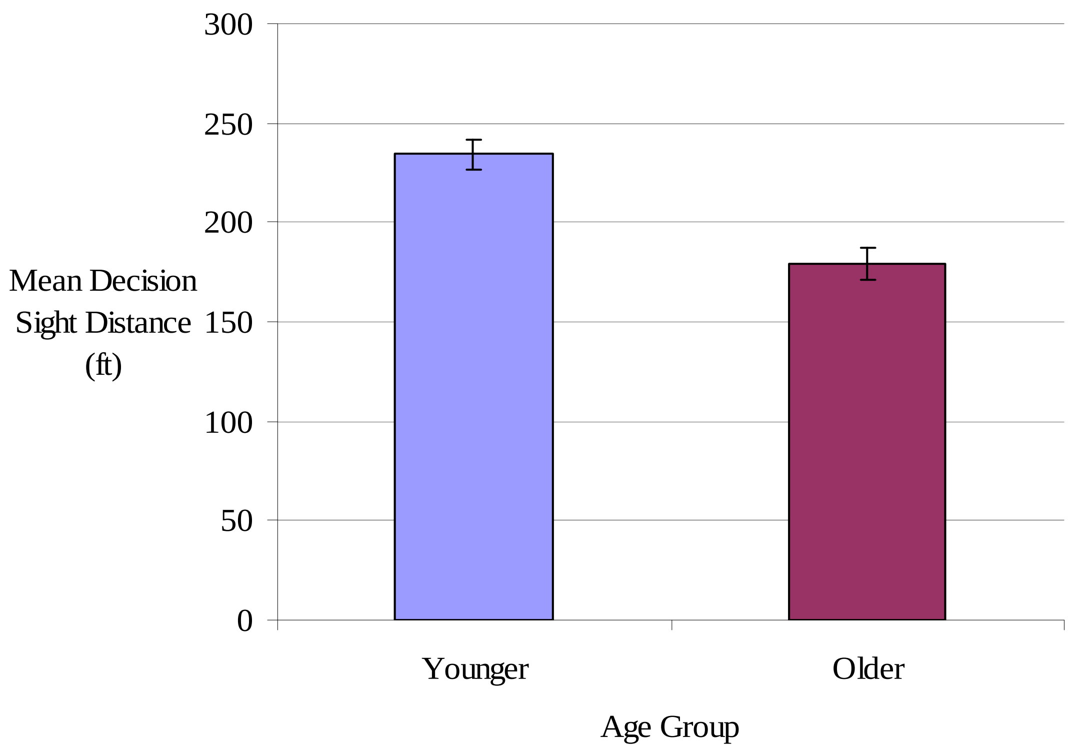


Figure 4. Mean Decision Sight Distance: Overall

As shown in Figure 5, (error bars depict the 95% confidence interval), when comparing the APL signs with the four other sign types, the APL signs were, on average, correctly interpreted at a significantly greater decision sight distance; $F(1, 2252) = 32.35$, $p < 0.001$. The lack on a significant interaction of sign type with age suggests that both younger and older drivers benefit from the additional decision sight distance afforded by the APL signs.

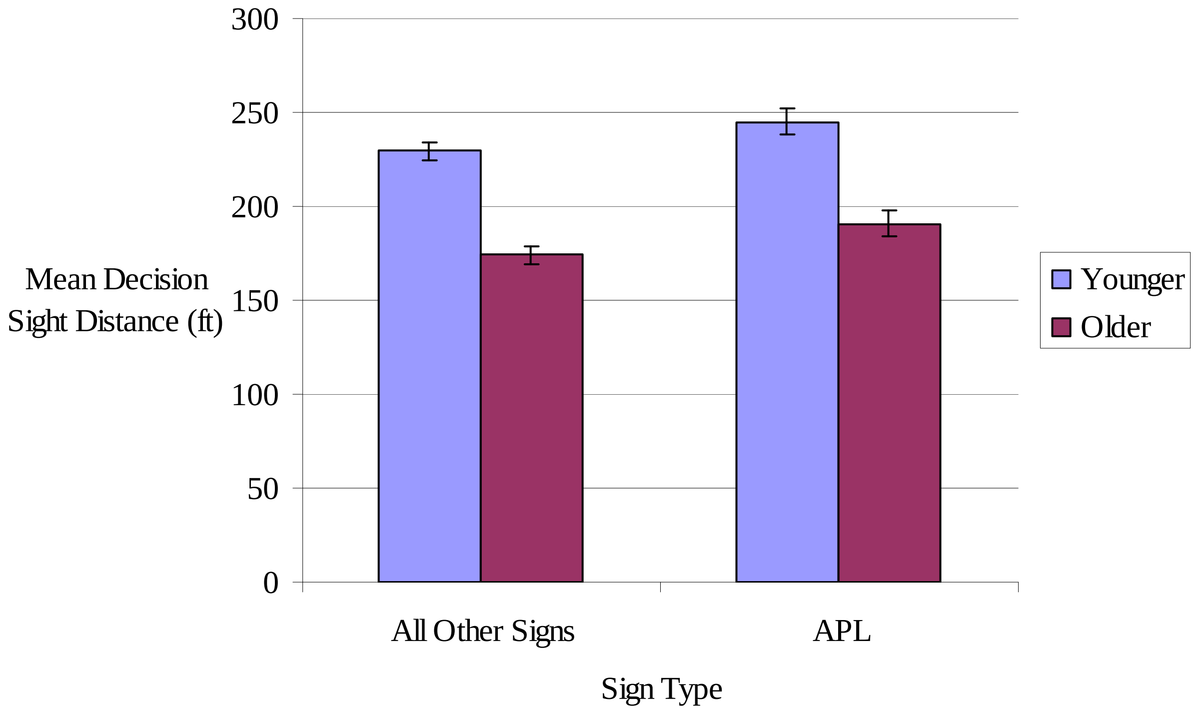


Figure 5. Mean Decision Sight Distance by Age Group, Comparing the Arrow Per Lane vs. All Other Signs

No other factors (i.e., highway type, type of exit, number of exit lanes, or direction of exit) yielded significant effects.

CORRECT LANE CHOICE

Older drivers made significantly fewer correct lane identifications than younger drivers. About 87% of the responses made by younger drivers were correct, while for older drivers, just over two-thirds of responses (70%) were correct.

As shown below in Figure 6, (error bars depict the 95% confidence interval), the older drivers mean percent correct lane choice was greater with the APL signs than with the other signs, but the younger drivers did equally well regardless of sign type. The interaction between sign type and age group was significant, $F(1, 2344) = 4.18$, $p < 0.05$.

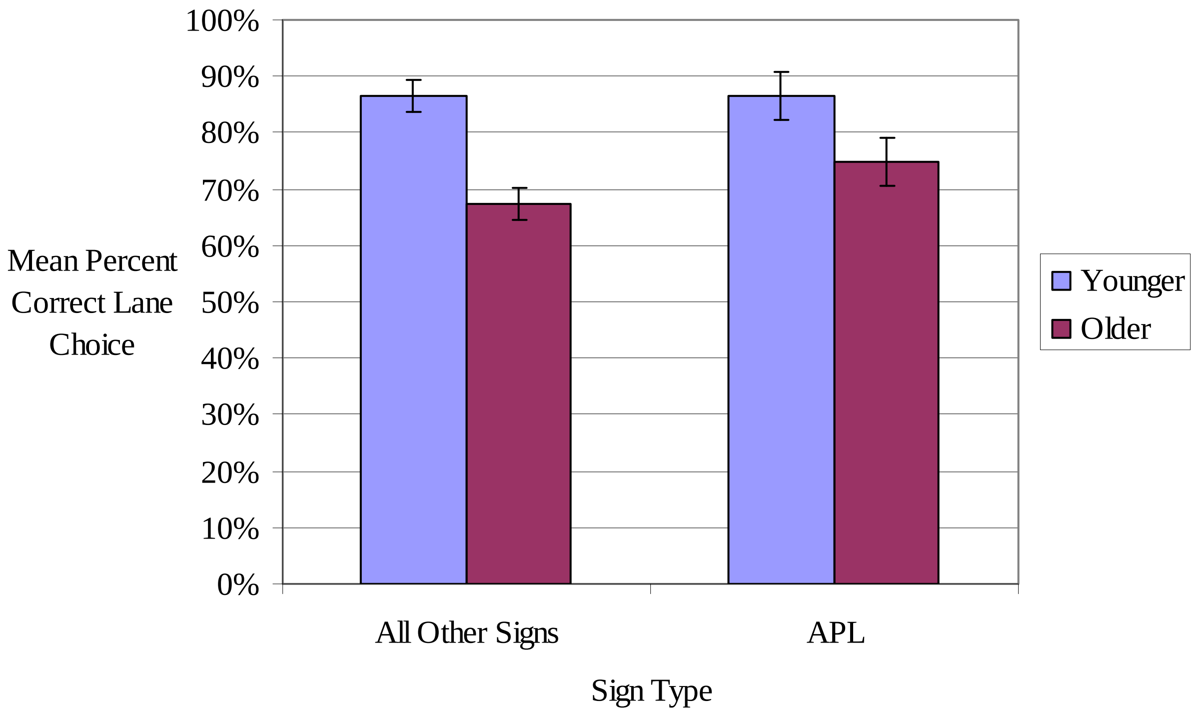


Figure 6. Mean Percent Correct Lane Choice by Age Group, Comparing the Arrow Per Lane vs. All Other Signs

The mean percent correct lane choices with the APL signs was compared to the mean percent correct with the other sign types, with and without option lanes. As can be seen in Figure 7, the average lane choice performance was significantly better with the APL signs when there were no option lanes. However, the superiority of the APL signs was not significant when there were option lanes, and performance was reduced when option lanes were present. The interaction of option lane presence with sign type was significant, F (1, 2340) = 8.1, $p < 0.01$. The option lane effect was stronger for older drivers than for younger drivers, and the interaction of age group and type of exit lane design was significant, F (1, 2344) = 4.7, $p < 0.05$. The latter interaction may have resulted from a ceiling effect – the circumstances may not have been challenging enough for the younger group to show superiority for the APL signs, even if there were one.

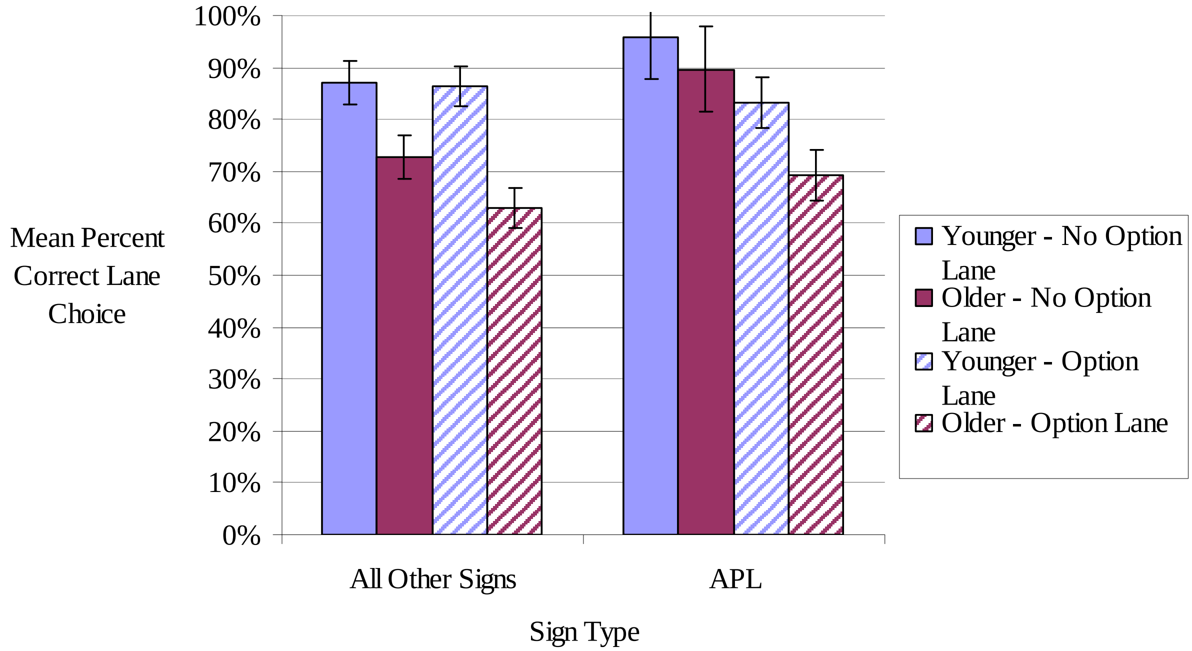


Figure 7. Mean Percent Correct Lane Choice by Sign Type, Presence of an Option Lane and Age Group

Exit direction, number of exit lanes, and highway type did not yield significant differences in percent correct responding.

CONCLUSIONS AND RECOMMENDATIONS

Older drivers made more correct lane choices with the APL signs than with the conventional signs. Older drivers consistently needed about 24 percent more distance to comprehend exit guide signs than younger drivers, regardless of the sign type. However, older driver decision sight distance was better with the APL signs.

In summary, both with regard to decision sight distance and correct lane choice, the APL sign provides superior navigation guidance. In order to fully test the APL sign, it is recommended that future research address:

- Increasing the font size to further increase decision sight distance
- Validating the findings from this study with field data or in an interactive driving simulation.
- Evaluating the APL sign with the Exit Only placard as appropriate.

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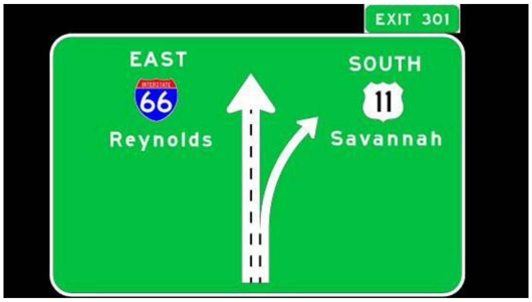
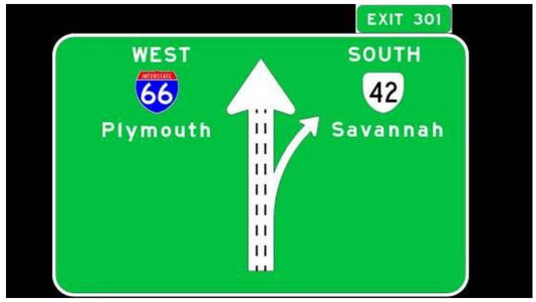
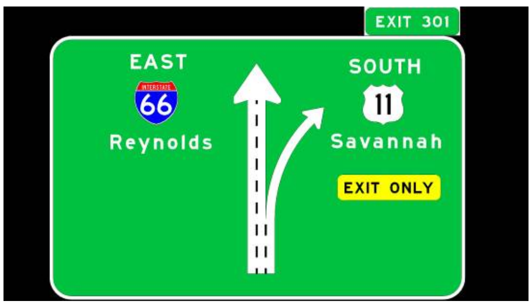
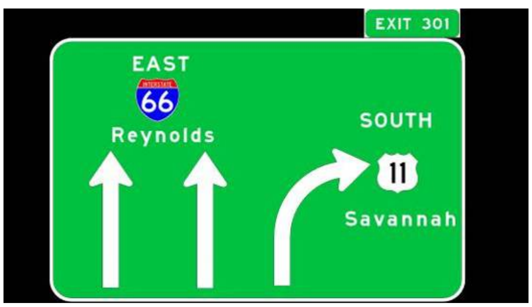
APPENDIX A: EXAMPLES OF EXPERIMENTAL SIGNS

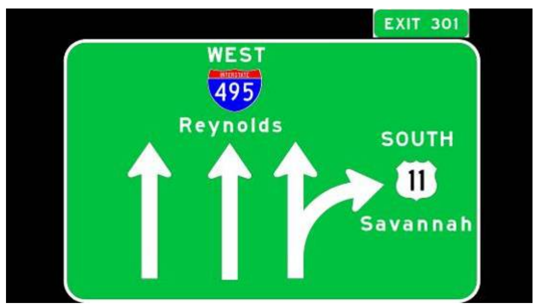
Right Exit, 3 Travel Lanes, Single Exit Lane



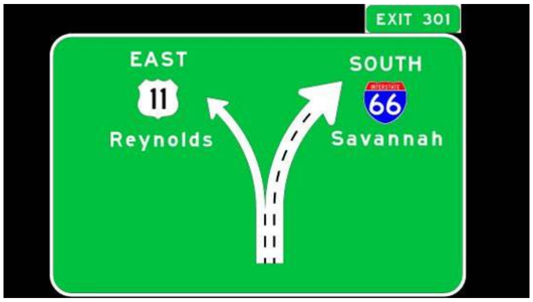


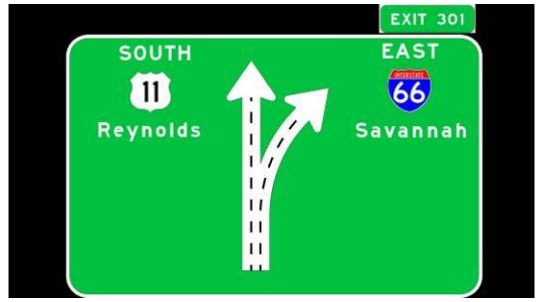


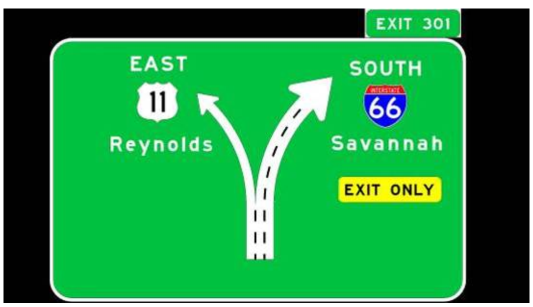


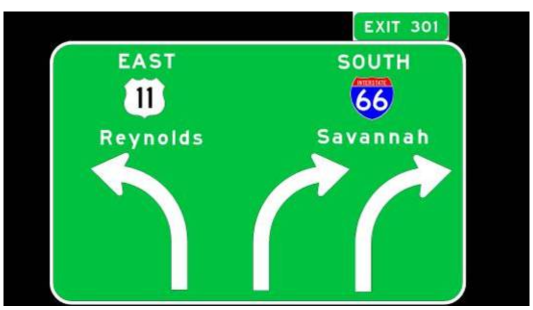


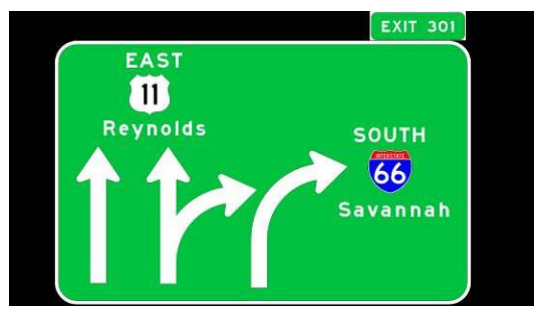
Right Exit, 3 Travel Lanes, Multiple Exit Lanes



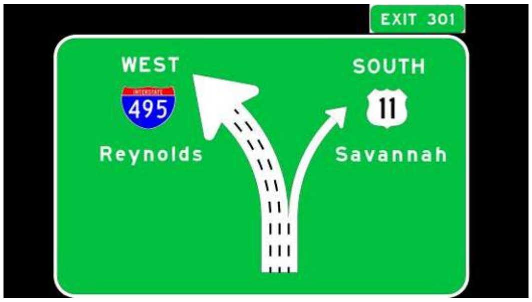


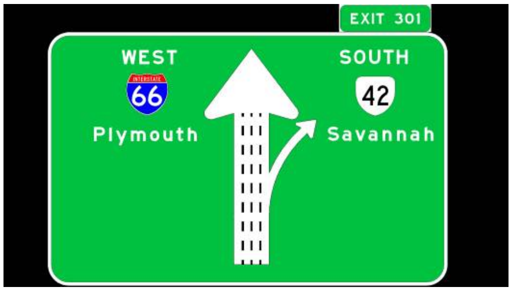


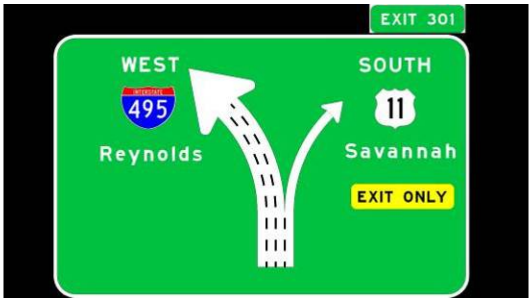


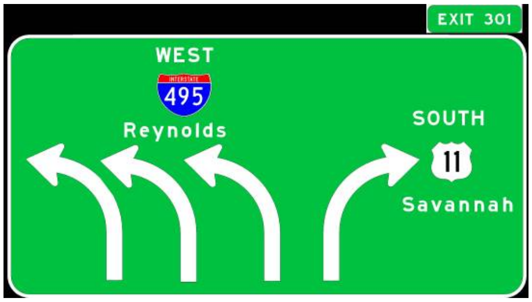


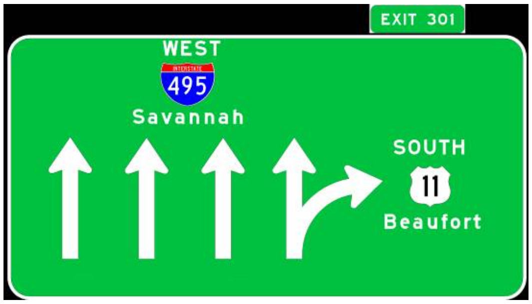
Right Exit, 4 Travel Lanes, Single Exit Lane



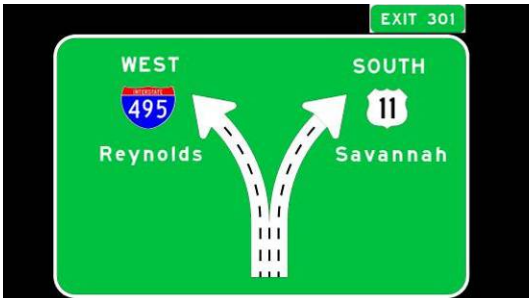


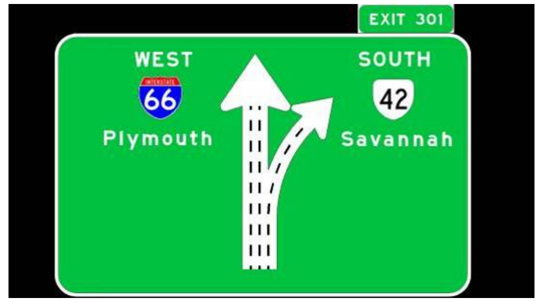


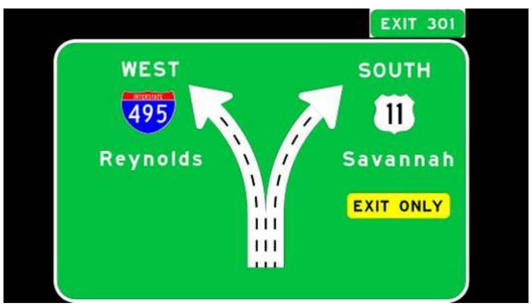


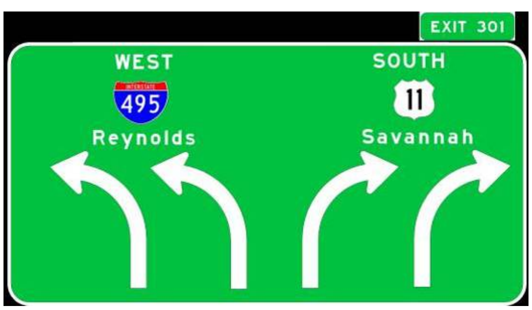


Right Exit, 4 Travel Lanes, Multiple Exit Lanes

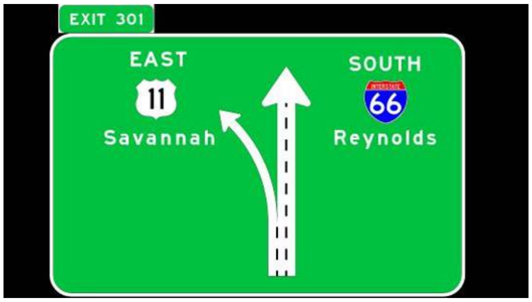


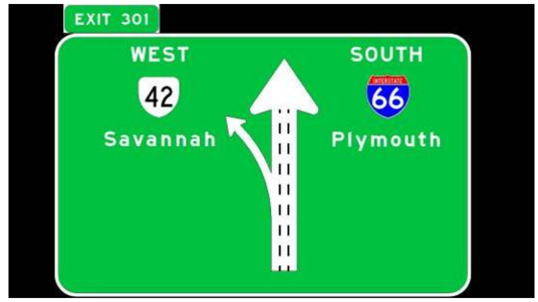


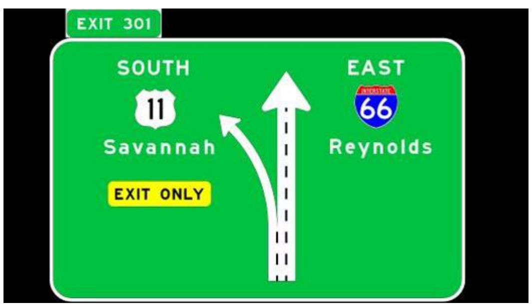


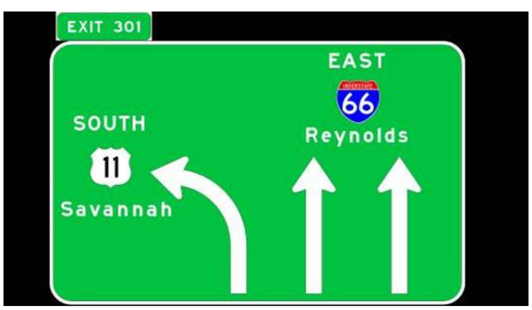


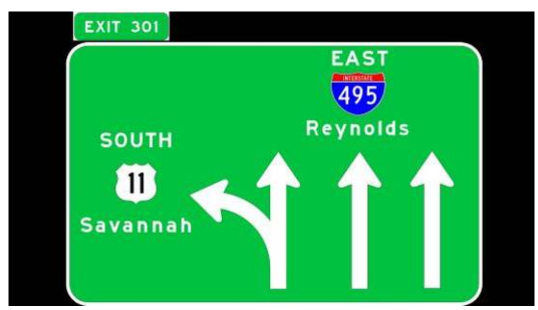
Left Exit, 3 Travel Lanes, Single Exit Lane



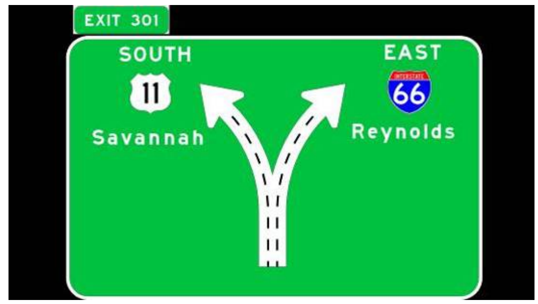


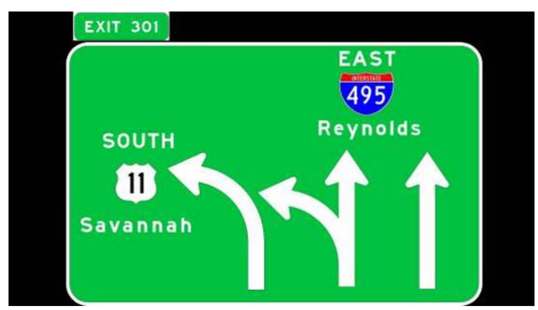




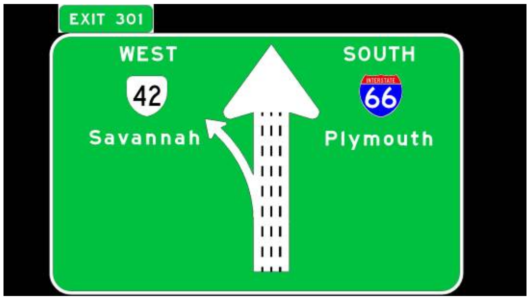


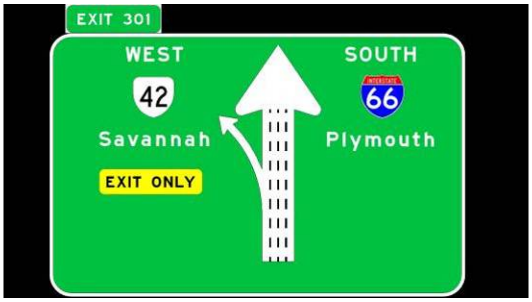
Left Exit, 3 Travel Lanes, Multiple Exit Lanes

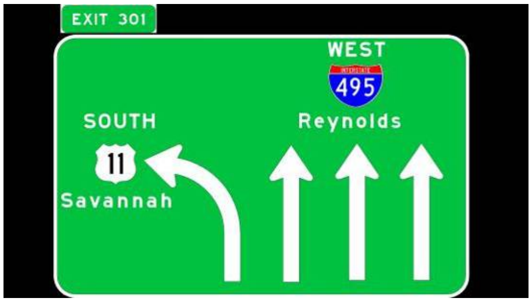


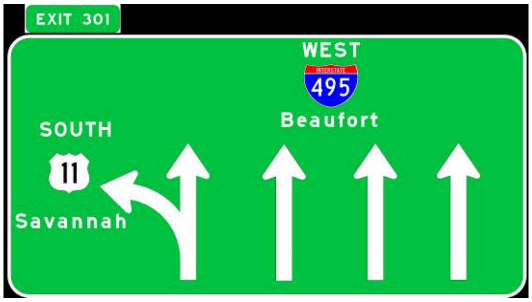


Left Exit, 4 Travel Lanes, Single Exit Lane









Left Exit, 4 Travel Lanes, Multiple Exit Lanes