

Arrow-per-Lane Guide Sign Research, Revisited

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ABSTRACT

Overhead Arrow-per-Lane guide signing for freeways first appeared in the Manual on Uniform Traffic Control Devices (MUTCD) (1) in the 2009 edition. The decision to include Arrow-per-Lane guide signing in the MUTCD was based upon a 2008 research project.

This paper revisits the 2008 research to better understand its findings and supplement it with additional recent research. The 2008 research that evaluated the Arrow-per-Lane design is reviewed, observations are made about that research, and aspects of a recent evaluation of the Arrow-per-Lane design are discussed.

The findings of this paper include the following. The height of arrows on Arrow-per-Lane signs are much larger than is needed. Diagrammatic signs serve as well as Arrow-Per-Lane signs in providing decision sight distance. The slightly greater decision sight distance for Arrow-per-Lane signs claimed by the 2008 research does not have a practical significance and does not justify nationwide major changes in signing standards. The conclusions of the 2008 research need to be questioned because not all of the conclusions are supported by research findings.

Keywords: Traffic Control Devices, Human Factors, signing

INTRODUCTION

Overhead Arrow-per-Lane guide signing for freeways first appeared in the Manual on Uniform Traffic Control Devices (MUTCD) (1) in the 2009 edition of the MUTCD. An example of Arrow-per-Lane guide signing is shown in Figure 1. The important MUTCD provisions for use of the Arrow-per-Lane design on freeways are as follows.

- Either Arrow-per-Lane or Diagrammatic guide sign designs shall be used for all multilane exits at major interchanges that have an optional lane for an exit and for all splits that include an option lane. This is a Standard.
- The Arrow-per-Lane guide sign design should also be considered for multi-lane exits with an option lane at intermediate interchanges. This is Guidance.
- The Arrow-per-Lane design shall be used on all new or reconstructed freeways. This is a Standard. In other words, Diagrammatic guide sign designs are not allowed on new or reconstructed facilities.
- In a Support statement, the MUTCD states that “At locations where an option lane is present at a multi-lane exit or split, Overhead Arrow-per-Lane guide signs have been shown to be superior to either conventional guide signs or Diagrammatic signs....”

Thus, the MUTCD places a strong emphasis on, and encourages use of, the Arrow-per-Lane design.

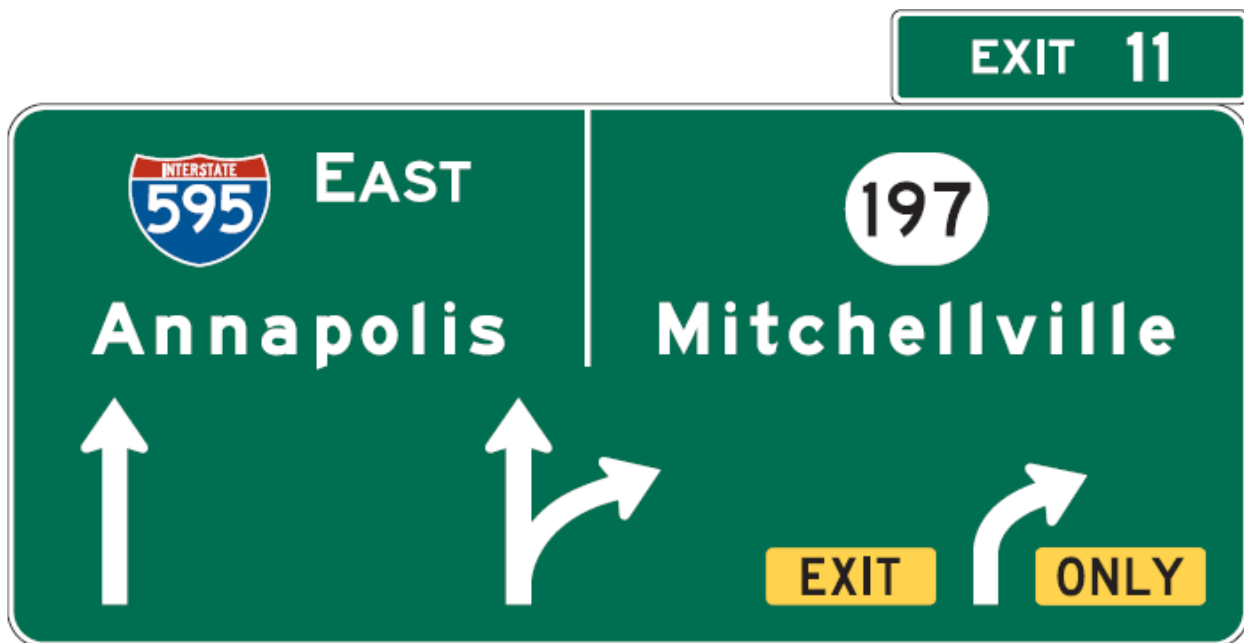


FIGURE 1 Example of Arrow-per-Lane Guide Sign as used for a Multi-Lane Exit with an Option Lane (reproduced from Reference 1)

The 2009 edition of the MUTCD was adopted by the Federal Highway Administration (FHWA) in a Final Rule published in the Federal Register on December 16, 2009. In adopting the Arrow-per-Lane design for guide signing in the Final Rule, FHWA cited a sole research project (2), the only research project which had been conducted on the Arrow-per-Lane design at that time, as justification for adopting the Arrow-per-Lane design. The Final Rule states: “a recent study... confirmed that [Arrow-per-Lane] design is significantly superior to the existing diagrammatic design...in terms of providing a longer decision sight distance and higher rates of road user comprehension.” In the following pages, this paper will refer to that study (2) as the “2008 research”.

The 2008 research had a subsequent significant impact on freeway guide signing in the United States. It is now worth revisiting that research to better understand its findings and supplement it with additional recent research. This paper reviews the 2008 research that evaluated the Arrow-per-Lane design, makes observations about that research, and discusses a recent evaluation of aspects of the Arrow-per-Lane design.

The work described in this paper is needed for the following reasons. The financial impact on highway agencies of the new 2009 MUTCD provisions for Arrow-Per-Lane signs is exceptionally large. There are questions about whether the findings of the 2008 research have been correctly interpreted. There is a question about whether the new 2009 MUTCD provisions for Arrow-Per-Lane signs was a good decision.

OBJECTIVES OF THIS PAPER

The objectives of this paper are to: 1) provide background on the 2008 Arrow-per-Lane research, its findings and conclusions; 2) describe a 2014 experiment which helps to better understand aspects of the 2008 research; 3) present results and interpretation of the 2014 experiment; 4) present observations about the 2008 research that support conclusions different from those found by the 2008 research; and 5) offer commentary on the impacts of the 2008 research.

2008 ARROW-PER-LANE RESEARCH

Introduction

To acquaint the reader with the 2008 research, this portion of the paper provides a summary of those portions of that research that are pertinent to this paper. In some instances text describing the study has been copied from the original report (2). The 2008 research was conducted to obtain additional empirical data with which to assess the effectiveness of the Arrow-per-Lane guide signs in directing drivers to a destination compared to various conventional guide sign alternatives. Two measures of effectiveness were obtained: decision sight distance and correctness of lane choice.

The research objective of the 2008 research was to compare the Arrow-Per-Lane design against the following conventional alternatives which are illustrated in Figure 2 (Sign Types):

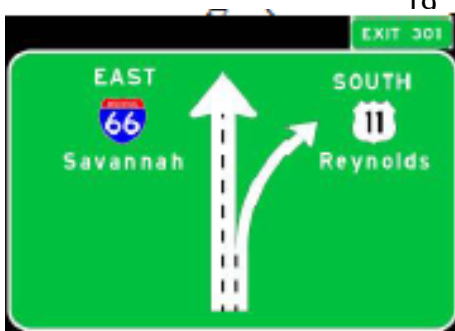
- A Diagrammatic design
- A Diagrammatic design with an added EXIT ONLY panel
- A Modified Diagrammatic design using wider lanes and arrow heads, and bolder lane lines
- A Modified Diagrammatic design with an added EXIT ONLY panel
- An Arrow-per-Lane design



Diagrammatic design



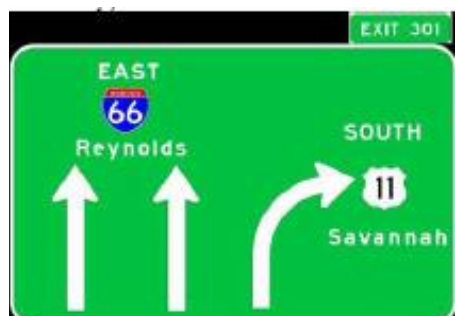
Diagrammatic design with an added EXIT ONLY panel



Modified Diagrammatic design using wider lanes and arrow heads, and bolder lane lines



Modified Diagrammatic design with an added EXIT ONLY panel



Arrow-per-Lane design

FIGURE 2 Examples of Sign Types Tested (Reproduced from Reference 2)

Research Methodology

“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.” (2)

“For the experiment, each trial began with the sign displayed at [a] 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.” (2)

“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..... 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.” (2)

“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 3. 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.” (2)

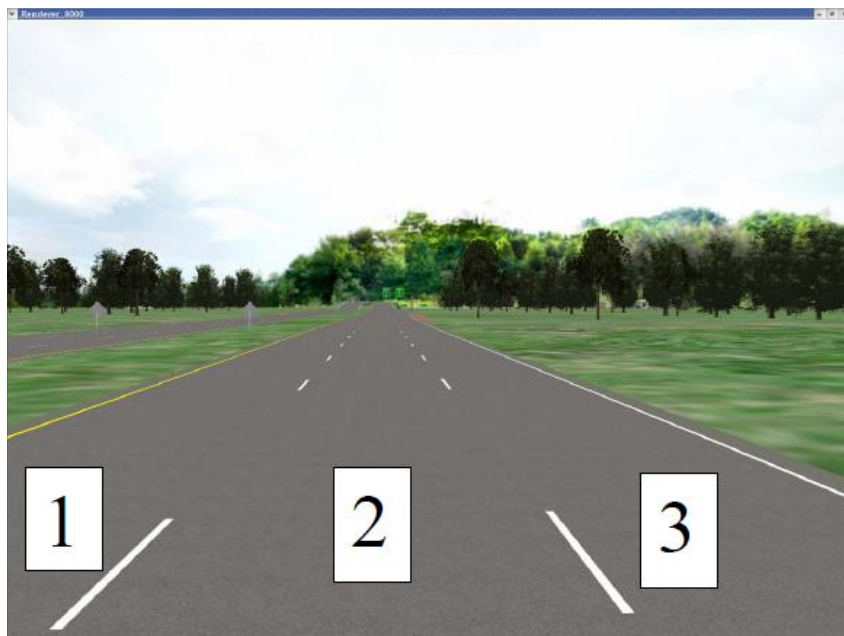


FIGURE 3 Example of Response Pad Screen Depicting 6-lane Roadway (3 lanes in each direction) with Lane Designations (Reproduced from Reference 2)

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 [(always Savannah)]. The simulated distance at which the participants made their first lane choice is referred to as the decision sight distance. Participants’ lane choices were scored as correct only if all possible choices were selected.” (2)

Experimental Conditions

Among other factors, The experimental conditions covered Sign Type, presence or absence of an option lane, and younger vs. older test subjects.

“Each participant viewed the same 49 signs. To minimize order effects, four different randomized sets of the signs were constructed. Each participant was randomly assigned one of the presentation orders.” (2)

Participants

“Forty-eight participants were recruited; with an equal number of men and women.” Half of the participants (older drivers) were over 74 years old. Half were under age 75. “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).” (2)

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 to the assigned destination 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.” (2)

As shown in Figure 4, (error bars depict the 95% confidence interval), when comparing the Arrow-per-Lane signs with the four other sign types combined, the Arrow-per-Lane signs were, on average, correctly interpreted at a significantly greater decision sight distance; $F(1, 2252) = 32.35, p < 0.001$.

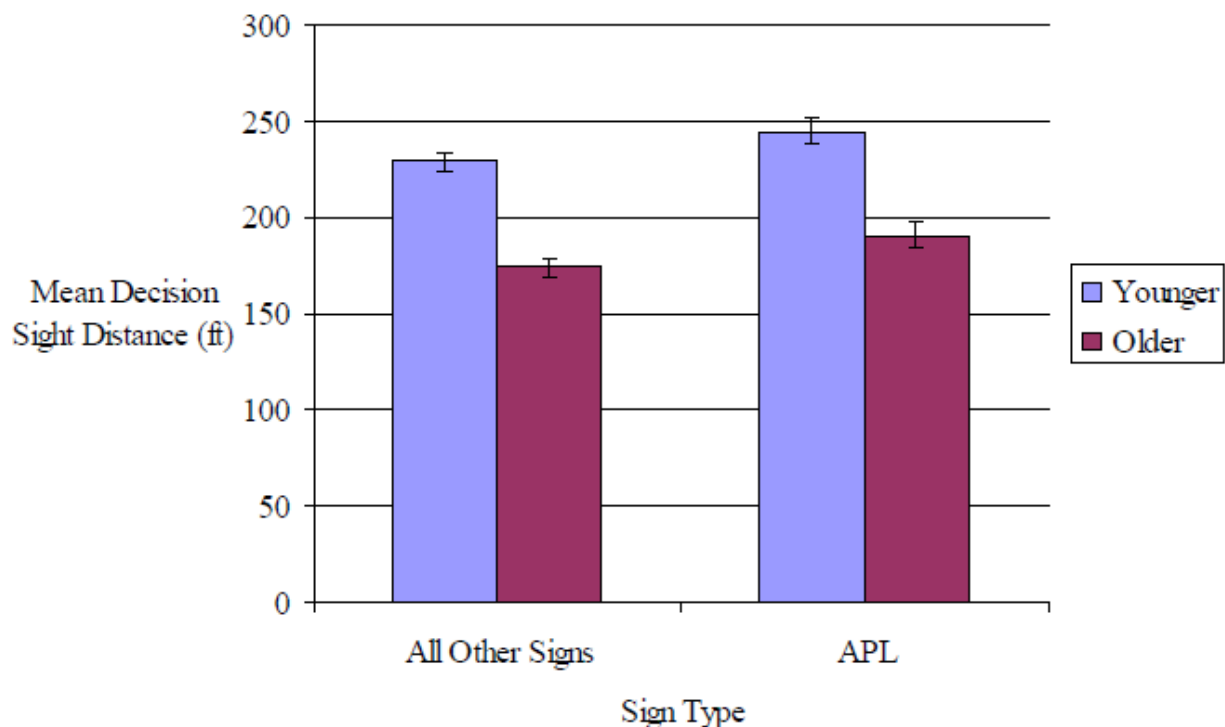


FIGURE 4 Mean Decision Sight Distance by Age Group, Comparing the Arrow-Per-Lane vs. All Other Signs

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 5, (error bars depict the 95% confidence interval), the older drivers mean percent correct lane choice was greater with the ...[Arrow-per-Lane] 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, $F(1, 2344) = 4.18, p < 0.05$.” (2)

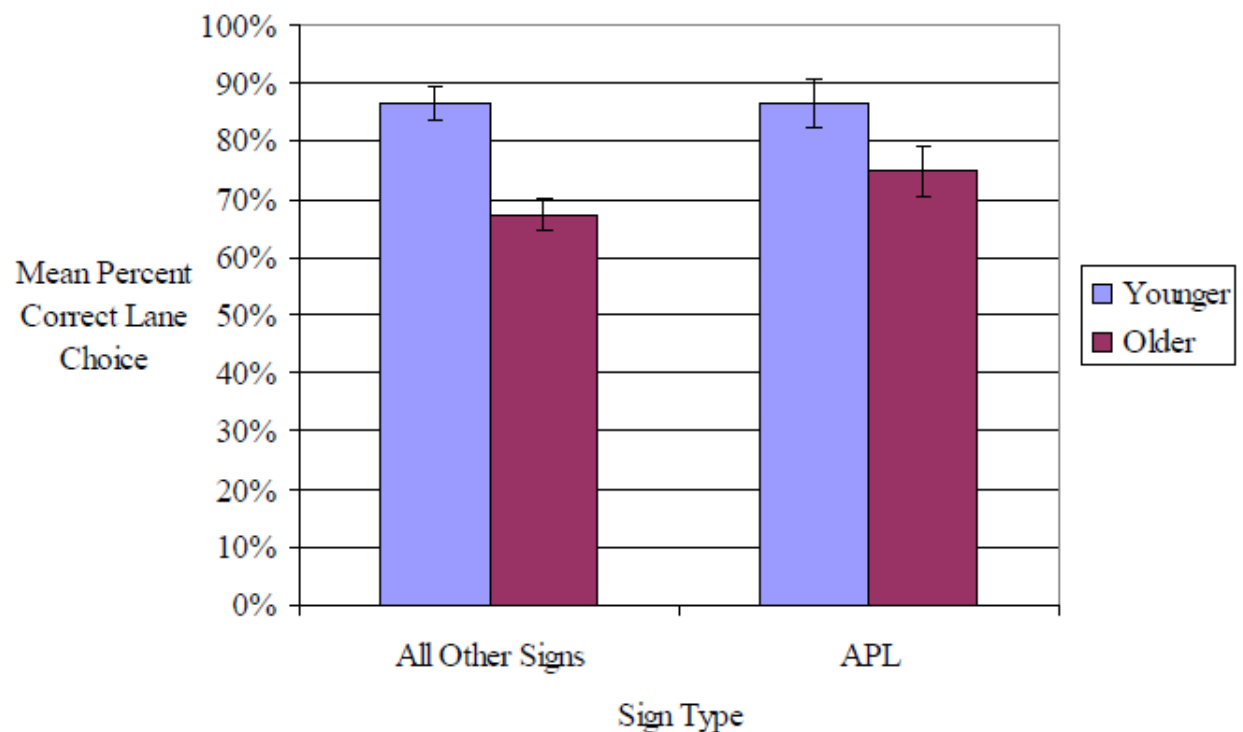


FIGURE 5 Mean Percent Correct Lane Choice by Age Group, Comparing the Arrow-Per-Lane vs. All Other Signs

“The mean percent correct lane choices with the ...[Arrow-per-Lane] signs was compared to the mean percent correct with the other sign types, with and without option lanes. As can be seen in Figure 6, the average lane choice performance was significantly better with the ...[Arrow-per-Lane] 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, $F(1, 2344) = 4.7, p < 0.05$.” (2)

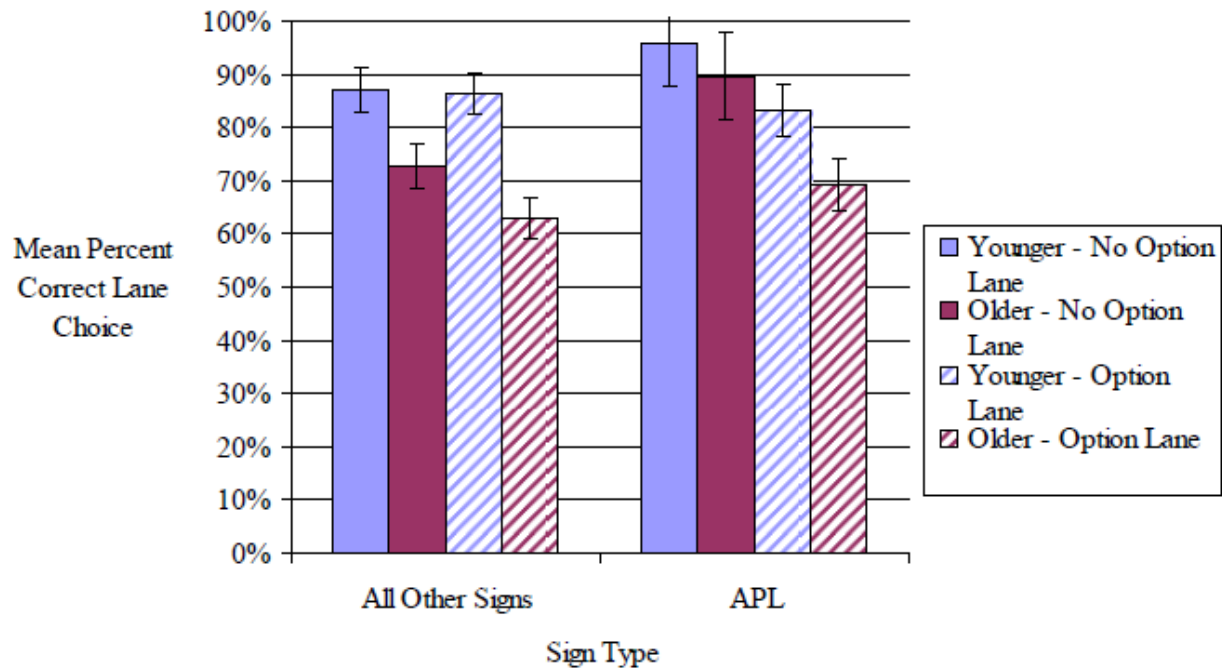


FIGURE 6 Mean Percent Correct Lane Choice by Sign Type, Presence of an Option Lane and Age Group

Conclusions of 2008 Research

“Both age groups made more correct lane choices with the Arrow-per-Lane signs than with the conventional signs. Older drivers especially benefited in this regard.

“Older drivers consistently needed about 10 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 Arrow-per-Lane sign provides superior navigation guidance.” (2)

2014 EXPERIMENT

A simple human factors experiment was conducted in 2014 to investigate aspects of the 2008 research. The following pages refer to this as the 2014 experiment. The purpose of the experiment was to better understand and interpret the meaning of the decision sight distances measured in the 2008 research. Two questions to be answered were: 1) Does the legibility of the destination names impact the decision sight distance? and 2) Is size of the arrow larger than necessary? While very simple in research methodology, the experiment clearly demonstrated selected points about the 2008 research.

Research Methodology

The methodology was designed to mimic that used in the 2008 research but in a way that avoided use of specialized laboratory equipment and allowed the experiment to be done in a typical conference meeting room. Four signs were prepared for viewing by test subjects, as shown in Figure 7. Two signs had destination names. The letter height was the same as that used in the 2008 research. These two signs simply replicated signs used in the 2008 research except that route shields, cardinal directions, and a diagrammatic or arrows were removed. A third sign was a Modified Diagrammatic design with the same size diagram as used in the 2008 research. A fourth sign was an Arrow-per-Lane design with arrows the same size as used in the 2008 research. The third and fourth signs simply replicated signs used in the 2008 research except that destination names, route shields, and cardinal directions had been removed. In place of destination names, large letters were used to indicate destinations. This was done so that test subjects could clearly see identifiers for destinations.

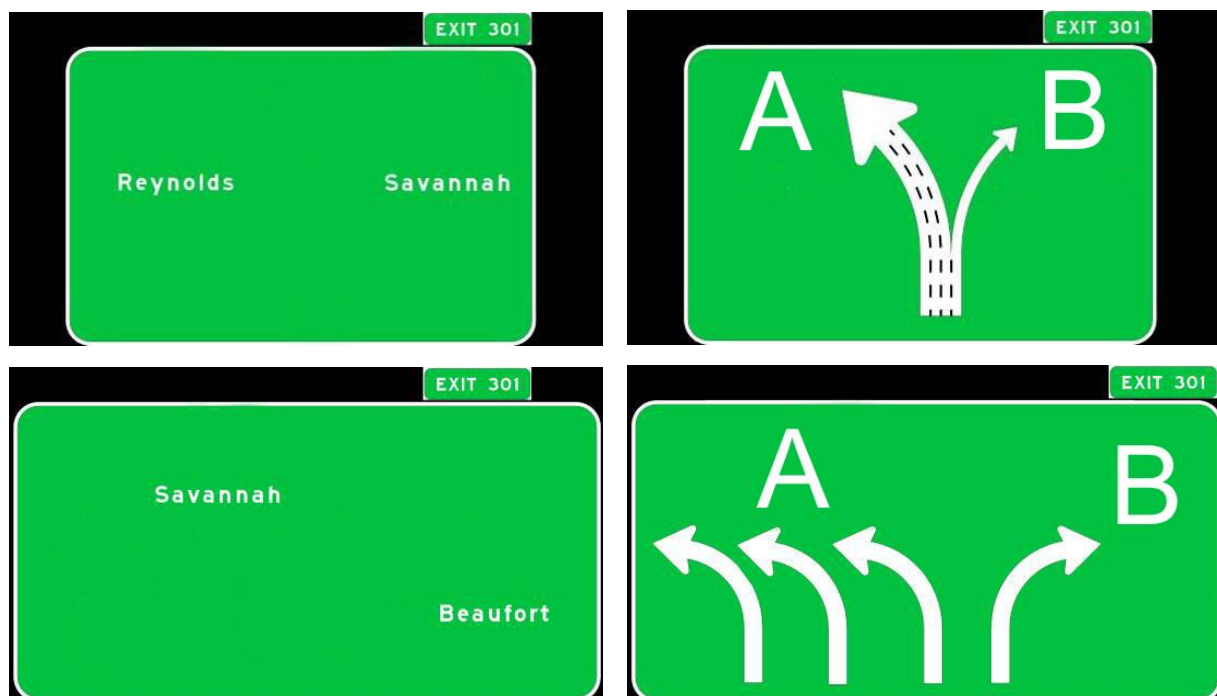


FIGURE 7 Four Signs used in 2014 Experiment

Using a PowerPoint presentation, each of these four sign designs was projected on a screen in a meeting room in which the test subjects were seated theater style. For each sign, the image was first shown at a size about one-twentieth of the full screen width. At two second intervals the sign image was gradually increased in size, until after either 16 or 20 increments the sign filled the screen width. Each set of images for a sign were numbered on the screen from 1 to 16 or 1 to 20.

The test subject participants were comprised of two groups. One group was 29 members of the Guide and Motorist Information Signs Technical Committee of the National Committee on Uniform Traffic Control Devices. The second group was 20 individuals who attended a meeting of the National Committee's Research Committee. Participants ranged in age from about ages 30 to 70. Most participants were male. Participants did not represent a controlled pool of test subjects, but it is believed that the experimental findings are similar to what would be found in a more controlled study.

Participants were provided a response form, a writing tool, and given the following instructions.

You will be seeing images of guide signs on the screen. Please sit where you have a good view of the screen. Move now if you need to. Once we begin the experiment, please don't change your location. Stay seated where you are.

You will be shown images of guide signs that you might see if you were driving on a freeway with four lanes in your direction of travel.

Some of the sign images will only show names of destination cities.

Some of the sign images will only show some type of arrow diagram that indicates the lanes on your freeway.

The sign images that you see will start out small (similar to how it would appear if it were far away on a highway) and will grow larger and larger (and appears to be getting closer to you). At first the signs will be so small that you will not be able to read anything on the sign. As the signs grow larger, you will eventually be able to make out the sign design and read it.

Each image of the sign will have a number in the lower left hand corner. When you are able to answer the question that you are asked, then look at the number in the lower left hand corner. This is the number you are to circle on your response sheet.

For those signs that have only names of destination cities, your task will be: When you are 100 percent sure that you can read the names of all the destinations on the sign, record the slide number.

For those signs that only show an arrow diagram, your task will be: When you are 100 percent sure that you know all the destinations that can be reached from each lane, record the slide number.

Participants practiced on two sets of signs and then the experiment was conducted with the four experimental signs.

Results, Findings, and Interpretation

Recall that the sign images started out very small (with a number 1 tagged to the smallest image size) and progressively became larger (with a number 16 or 20 tagged to the largest image size). Participants recorded the image size number when they were able to accomplish a task; i.e., be certain they could read the destination names; or when they were sure that they knew all the destinations that could be reached from each lane. In this experiment, it did not matter that participants sat at varying distances from the screen and that those sitting closer to the screen would be able to respond sooner than those who were seated farther away. This experiment was simply interested in, for each test subject, the relative image sizes associated with the responses to each task. Table 2 presents the results in terms of the average image size for each task.

TABLE 2 Image Sizes for Each Task

Task	Average of the recorded image numbers
Were able to read destination names	6.47
Understood which destinations could be reached from each lane – Diagrammatic sign	6.20
Understood which destinations could be reached from each lane – Arrow-per-Lane sign	2.61

The above results yield three key findings.

1. A smaller average number means that the participant could accomplish the task at a greater distance from the sign. A larger number means that the participant needed to be closer to the sign. Destination names had a shorter legibility distance than the distances associated with the two tasks of understanding which destinations could be reached. This means that while test subjects could complete the understanding task earlier, they would have to wait until destination names were legible to make a lane choice or choices.

What does this mean in terms of the 2008 research? It reveals that while the 2008 research was attempting to compare the effectiveness of different sign designs to inform drivers about the lanes that could be used to reach a destination, the experiment was actually doing something else. It, instead, was likely measuring the legibility distance of the destination names.

The 2008 research presents a hint that this is likely true. The mean decision sight distances in Figure 4 are not much different between Arrow-per-Lane signs and all other signs (only a 15 feet difference for younger subjects and 17 feet difference for older subject). Intuitively, when looking at Figure 2, one would expect a much larger difference in decision sight distance between Arrow-per-Lane and diagrammatic signs if it was the effectiveness in communicating the proper lane(s) that was being measured. Because there is a very small difference, it strongly suggests the idea that what was measured in the 2008 research was the legibility distance of the destination names and it was not a measurement of the distance at which the sign images were effective in communicating which lanes lead to each destination.

2. The distance at which test subjects understood which destinations could be reached from each lane on a Diagrammatic sign was still greater than the distance at which the destination names could be read. The understanding task could be accomplished at an image size of 6.20. The reading of destination names task could be accomplished at an image size of 6.47. What this means – in practical terms – is that a Diagrammatic sign design is just as good as an Arrow-per-Lane sign. If the driver can determine which lanes go to where, before being able to read the destination names, it is the legibility of the destination names that controls when the driver is able to make a decision about lane choice and all sign designs are equally good in terms of how far in advance of the gore a driver knows what lane(s) leads to his destination.

3. The Arrow-per-Lane signs in the 2014 experiment allowed participants to understand which destinations could be reached from each lane long before the destination names could be read. The numbers indicate that the arrows could be only half the size as shown on the experimental signs and drivers would still understand which destinations could be reached from each lane long before being able to read the destination names. For example, test subjects could understand which destinations could be reached from each lane for the Arrow-per-Lane sign at an image size of 2.61. If the arrows had been only half as large on the sign, test subjects would understand which destinations could be reached at an image size of $2 \times 2.61 = 5.22$. If that image size were used, test subjects would still be understanding which destinations could be reached sooner than they could read the destination names (image size of 6.47).

The height of the Arrow-per-Lane arrows on the signs used in the 2008 research and the 2014 experiment are about 60 inches. When FHWA included the Arrow-per-Lane design in the 2009 MUTCD, the agency prescribed through arrows that were 72 inches tall. FHWA subsequently corrected the height to 66 inches tall in the list of known errors for the 2009 MUTCD. The 2014 experiment shows that those arrows are still much larger than they need to be.

Overhead Arrow-per-Lane signs are larger than other forms of guide signing. Several state departments of transportation have raised concerns about the large sign size that is needed for an Arrow-per-Lane sign. The sign must be wider because it must provide an arrow over each lane. In addition, the sign height is higher because the through arrows are required to be 66 inches tall. Increased sign width and height adds both weight and wind load to the support structure. For one new freeway facility in Florida, the state Department of Transportation estimated that the additional cost (for both sign and sign structure) for an Arrow-per-Lane sign, compared to a traditional sign design, would be \$500,000 per sign structure. For reconstructed freeway facilities, an existing overhead sign bridge would often need to be replaced due to the additional structural load. The 2014 experiment demonstrates that arrows could be much shorter /smaller and thus reduce the sign size problem.

Although the 2014 experiment had a simple research methodology and utilized an unscreened group of participants, the above results, findings, and interpretations would likely be unchanged if a more robust version of this experiment were conducted. For the two tasks performed by the participants – a legibility distance task and selection of destinations that can be reached from each lane – it is my opinion that the participants had no special knowledge that allowed them to perform better than the general public.

1 ADDITIONAL OBSERVATIONS ON 2008 RESEARCH

2 One of the two measures of effectiveness used in the 2008 research was decision sight distance
3 (the distance from the sign at which test subjects confidently believed they could make a lane
4 choice). A comparison of mean decision sight distance between the Arrow-Per-Lane design and
5 conventional diagrammatic designs showed that the Arrow-Per-Lane signs, for Younger test
6 subjects, had decision sight distance that is 15 feet more than conventional diagrammatic signs
7 (Figure 4). This is equal to 0.17 seconds at 88 feet per second (60 mph). For Older test subjects
8 the Arrow-Per-Lane design had 17 feet more of decision sight distance (0.19 seconds at 88 feet
9 per second). It is important to point out that the signs that were being tested were advance guide
10 signs that would likely be located one-half to one mile in advance of the gore. Does it truly
11 matter whether the decision sight distance is 5295 feet from the gore rather than 5280 feet from
12 the gore? Is this improvement large enough to justify nationwide major changes in signing
13 standards as required by the 2009 MUTCD?
14

15 The second measure of effectiveness was correct lane choice (the selection of a proper
16 lane to reach an assigned destination). The 2008 research (2) reports that for Younger test
17 subjects, conventional diagrammatic signs (actually, four variations of conventional
18 diagrammatic signs, the results of which were lumped together in a group) performed equally
19 well as the Arrow-Per-Lane design. Older test subjects did perform slightly better with the
20 Arrow-Per-Lane design, but it was not reported whether this difference was statistically
21 significant (Figure 5).
22

23 More importantly, one of the variations of the conventional diagrammatic sign that was
24 tested (the Diagrammatic with EXIT ONLY design) outperformed the Arrow-Per-Lane design
25 for both younger test subjects and older test subjects. Although this finding was not disclosed in
26 the final report (2), it was reported in the unpublished draft final report (3) (Figure 8). In other
27 words, the Arrow-Per-Lane design was outperformed by a variation of the conventional
28 diagrammatic design.
29

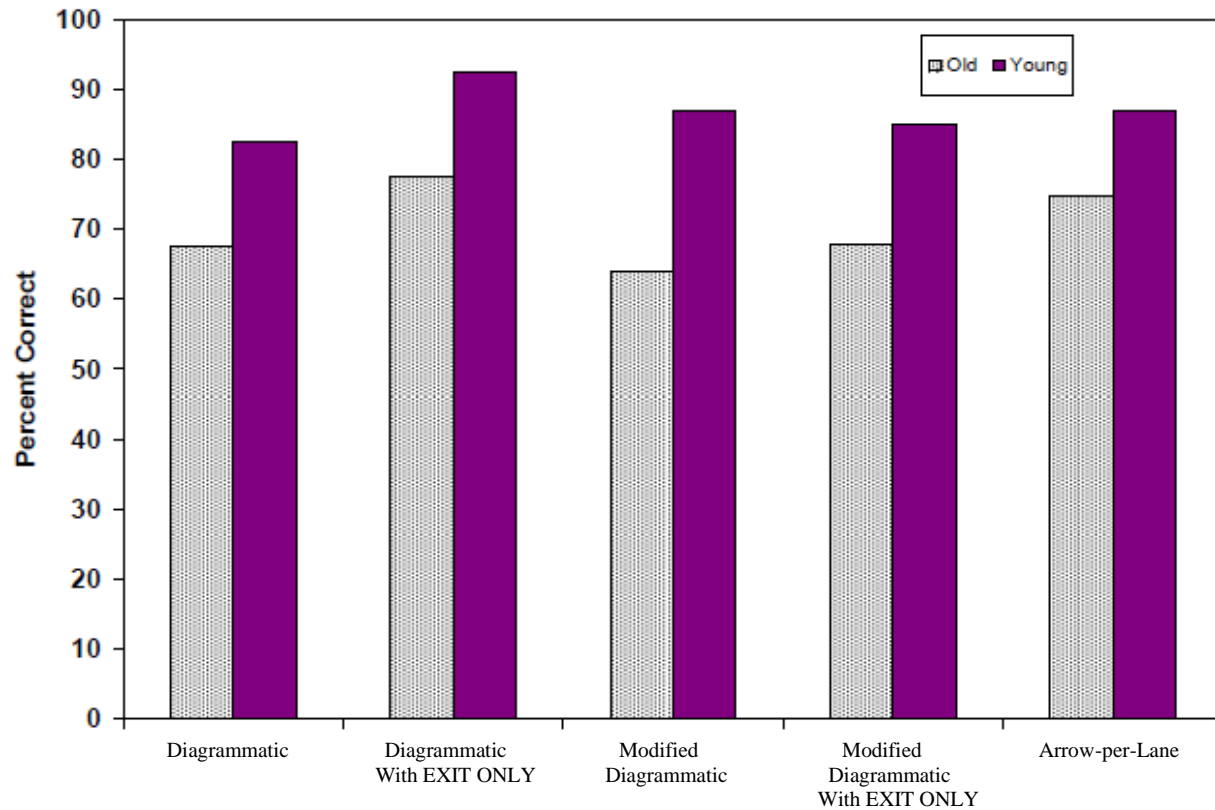


FIGURE 8 Percent Correct Lane Choice by Sign Type

The conclusions of the 2008 research need to be questioned. Those conclusions state that, “Both age groups made more correct lane choices with the...[Arrow-per-Lane] signs than with the conventional signs.” (2) Figure 5 shows that this was not true for Younger test subjects and the statement is also contradicted by the immediately preceding text which states that, “the younger drivers did equally well regardless of sign type.” The conclusion is not supported by the research findings.

COMMENTARY

The 2008 research was conducted to help establish policy and standards for use of traffic control devices. In fact, the study report was cited in federal rulemaking as justification for adopting a change in national standards. For one state, the Arizona Department of Transportation (ADOT) has estimated a statewide cost of \$35 million for ADOT to comply with the new option lane signing standards. Nationwide, this change in standards will likely result in additional costs to state departments of transportation of \$100 million or more. Federal officials who made the decision to make a change in national standards likely did so based on the report conclusions, and without understanding that those conclusions were not supported by the study findings.

CONCLUSIONS

The 2014 experiment clarifies and helps to better understand some of the 2008 research results. As carried out, the 2008 research methodology did not actually determine a decision sight distance that was based upon a sign's ability to successfully communicate what destination(s) could be reached by each lane. Instead, the decision sight distance was a function of the legibility distance of destination names on the test signs. Because the legibility distance of destination names controls the distance at which drivers can determine what destination(s) can be reached by each lane, diagrammatic signs serve equally well in providing decision sight distance.

The height of arrows on Arrow-per-Lane signs are much larger than is needed. A reduction in arrow size can reduce the overall size of Arrow-per-Lane signs and thus reduce the cost of both the sign and the support structure.

The slightly greater decision sight distance for Arrow-per-Lane signs claimed by the 2008 research does not have a practical significance and does not justify nationwide major changes in signing standards.

The conclusions of the 2008 research need to be questioned because not all of the conclusions are supported by research findings.

The MUTCD states that "At locations where an option lane is present at a multi-lane exit or split, Overhead Arrow-per-Lane guide signs have been shown to be superior to either conventional guide signs or Diagrammatic signs..." This statement is not supported by Arrow-per-Lane research conducted to date.

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