

# Perception Thresholds for Augmented Reality Navigation Schemes in Large Distances

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## ABSTRACT

Because the resolution of see-through displays is lower than the resolution of the human eye, perception of AR schemes is complicated in large distances. To discover, how design issues of perception correlate with presentation in large distances, we developed three different variants of arrow-based route guidance systems. With a large-scale Head-Up Display having a large focal depth, we tested the variants under different conditions on perception and interpretability.

**Index Terms:** H.1.2 [Models and Principles]: User/Machine Systems—Human information processing H.5.2 [Information Interfaces and Presentation]: User Interfaces—Prototyping

## 1 INTRODUCTION

Navigation systems incorporating Augmented Reality (AR) address mapping issues between route guidance information and the environment. An issue of location-fixed navigation information arises through display technology. In general the resolution of such AR displays is lower than the resolution of the human eye [1]. Especially at large distances, virtual objects presented in AR displays become pixelized. Perceptibility is reduced because the scheme only consists of very few pixels.



Figure 1: A Navigation Arrow superimposed in the Head-Up Display in a distance of 20 m

To determine the effects of presentation scheme design on perceptibility in large distances, we conducted an experiment. A driving simulator platform was extended with a large-scale Head-Up Display (HUD). Different schemes of route guidance arrows (see Fig. 1) were designed and tested in a user study regarding perception at different speeds.

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## 2 RELATED WORK

Gupta [4] investigated user context switches between real worlds and augmented information with an HMD to identify effects of focal accommodation and focus depth on task performance in augmented reality systems. Results of his study revealed that switching between real-world and virtual information in augmented reality is extremely difficult when information is displayed at optical infinity. Livingston [6] investigated perception aspects of visual acuity, contrast sensitivity and color perception with different AR displays. For Head-Mounted Displays he objectively measured that the limited graphical resolution, reduced brightness, and uncontrollable visual context of the merged environment demonstrably reduce the visual capabilities of the users.

## 3 PRESENTATION CONCEPT

The general design of our three navigation aids is based on the German *Guidelines for the Marking of Roads*, part 2, *Application of Roadway Markings* [3]. We changed the color of our arrow variants to green to enable differentiation to lane indications. We widened the width of the arrow-heads and the width of the shaft to enhance direction determination in large distances. Arrows were designed for three types of route indication: 90 degree left, 45 degree diagonal left, straight, 45 degree diagonal right and 90 degree right.



(a) Variant A – Solid with Hard Corners (b) Variant B – Flat Arrow (c) Variant C – Solid with Rounded Shape

Figure 2: The three Variants of the Arrow-based Waypoint Guidance Scheme

To test the effects of presentation schemes with and without a spatial size, we gave a certain height to the arrow scheme. Variant A, the *cubed* scheme, shown in Fig. 2(a), was designed with a height of 10 cm. The height was chosen to generate the impression that the car can drive over the scheme without any damage to the car. The similar variant B, the *flat* scheme with no height is shown in Fig. 2(b). Based on the assumption, that a rounded shape increases spatial perception, we designed variant C (see Fig. 2(c)), a *rounded* scheme with a maximum height of 10 cm. The shaft of the arrow in this scheme consists of a cylinder and the arrow-head of a cone. Directional light for enhanced perception of the shape of the scheme faced left and down by each 45 degrees.

## 4 EXPERIMENT

The experiment was conducted in a fixed-base driving simulator. To face the strong dependency to display issues, we built a HUD similar to the HUD setup of Bergmeier [2]. The display had a resolution of 1680x1050 pixels. A lens generated a field of view of 34 degrees. A pixel thus had a relative size of about 3.5 cm in 100 m distance. The lens also moved the focal plane to a distance of 13 m. At this

distance, the depth of field reaches up to infinity. The driving simulator was placed in a straight hallway, 120 m long.

Sixteen individuals, 14 males and 2 females between the ages of 21 and 31 (mean 25.5, standard deviation 2.94), participated in the user study.

We applied a single-session within-subject design. The scheme appeared at a random distance between 320 and 250 m and moved at a predefined speed towards the driver. As soon as identified, the test subject indicated the direction of the scheme (left, diagonal left, straight, diagonal right and right). This procedure was repeated for all schemes in all orientations with two speeds (50 km/h and 100 km/h).

The *independent variables* were the selected presentation scheme (Variant A, B, C) and speed (50 and 100 km/h). The *dependent variables* used to quantify the quality of the visual schemes were the distance of perception and the error quotient. With a NASA TLX [5] questionnaire, the test subjects were asked, how their workload was affected.

## 5 RESULTS AND DISCUSSION

A one-way ANOVA was used for the analysis of more than two variants. The  $\alpha$ -threshold used in the pair-wise analysis is 0.05. A significant difference is indicated by arrows with two arrow-heads above the corresponding column bars. When the  $\alpha$ -value was larger than 0.25, the results are treated as equal and are indicated by a simple line above the two corresponding value-bars.

### 5.1 Objective Results

Due to interpretation errors, not all measured values could be taken into account. Scheme A was indicated wrong in 12 cases, scheme B in 4 cases and scheme C in 10 cases.

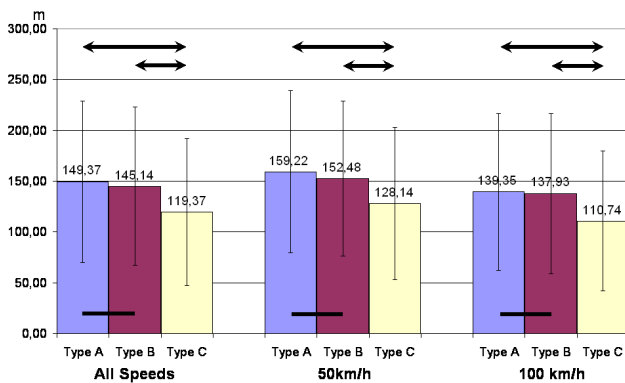


Figure 3: Objective Results for the different Arrow Types under different Speed Conditions

**Hypothesis:** *There is a perceptibility difference between the types of direction indication in general and when driving either 50 km/h or 100km/h.* Fig. 3 presents the results for the perceptive distance of all three visualization schemes ( $F = 21.15, p(ANOVA) = 0.000, \alpha(Levene) = 0.001$ ). The rounded arrow scheme C required significantly lower distances for perception than both other schemes. The rounded design, originally generated for enhanced perception of shape decreased perception.

All mean values of the distance of perception at 50 km/h have higher values than the summarized inspection. Similar to the summarized inspection, the rounded arrow scheme C was significantly worse compared to both other schemes ( $F = 10.53, p(ANOVA) = 0.000, \alpha(Levene) = 0.134$ ).

At 100 km/h, it takes longer to perceive the direction of the presentation schemes. Again, the rounded arrow shape C is signifi-

cantly worse than both other schemes ( $F = 10.87, p(ANOVA) = 0.000, \alpha(Levene) = 0.003$ ).

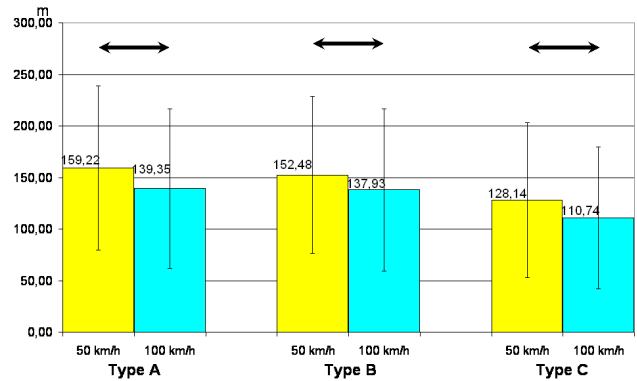


Figure 4: Objective Results for the different Speed Conditions of the different Arrow Types

**Hypothesis:** *There is a difference between driving 50 km/h and driving 100 km/h.* Fig. 4 shows the results for the speed analysis of the three arrow types. Driving at different speeds, the perceptive distance gets significantly ( $\alpha = 0.007$ ) worse with higher speeds. Higher speeds generate faster changes in the pixels of the existing shape. The higher this rate, the more difficult is the perception of the shape.

The results for arrow type B are similar to the corresponding results for arrow type A: differences are significant. In contrast to the previous result, the  $\alpha$ -value (0.041) is much closer to the  $\alpha$ -limit of 0.05.

The  $\alpha$ -value of arrow type C is significant ( $\alpha = 0.009$ ) and in the same range as the cubed scheme A.

## 6 CONCLUSION AND FUTURE WORK

Our results, in contrast to our early assumption, show that rounded shapes reduce perception in large distances. Further results show that perception of the flat arrow scheme suffers more from different speeds than both other schemes. Subjective questionnaires did not show any significant differences in workload as measured by the TLX.

Our future work will continue developing AR navigation systems with the cubed scheme. We will investigate the effects coloring the arrow edges in different colors for further enhancing perception in large distances. We finally will incorporate the system into real car to study effects of occlusion through other cars and to determine effects of distraction and cognitive workload.

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