Explore the navigation system of Augmented Reality Head-Up Display (AR-HUD) and traditional Head-Down Display (HDD) in influencing the driver's behavior in bad weather

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ABSTRACT

This research focused on comparing the influence of the navigation system of AR-HUD and traditional HDD on driving behavior and the effect of the two AR-HUD navigation concepts on surrounding perception. We conducted the car simulator experiment and analyzed the eye movement data, behavioral response and subjective evaluation. Results affirmed that AR-HUD navigation could effectively help users in bad weather. It is also proposed that the harpoon concept has certain advantages in the user's perception of surrounding things.

INTRODUCTION & BACKGROUND

Navigation system development

With lousy weather factors, unfavorable driving conditions such as poor visibility would occur. This limitation forces the driver to focus on a narrower view and requires more frequent scanning diversions to gather sufficient information. Navigation is particularly important when driving on unfamiliar roads. However, the difference between the navigation of AR-HUD and HDD in driving behavior in bad weather is still under-explored.

AR-HUD navigation concepts

Based on comparative AR-HUD navigation studies, the harpoon and solid fishbone concepts are considered to have certain advantages and are more widely used (Schneider et al., 2019). While traditional navigation is the technological maturity. So the following three concepts were selected for comparison.

Reference: Schneider, M. et al. (2019) 'A real-world driving experiment to collect expert knowledge for the design of AR HUD navigation that covers less'. Available at: https://doi.org/10.18420/MUC2019-WS-610.

In-dash navigation   Solid fishbone   Harpoon

RESEARCH QUESTION & HYPOTHESES

Q1: Does the AR-HUD navigation system help drivers in bad weather compared to the tradition?

H1: In bad weather, it is easier for drivers to perceive the navigation information from the AR-HUD than traditional navigation.
H2: In bad weather, the drivers focus more on the road with the AR-HUD navigation system than on the traditional one.
H3: In bad weather, the driver's response behavior and time are significantly quick for navigation with AR-HUD.

Q2: Do the different AR-HUD navigation concepts (solid fishbone and harpoon) influence the drivers' ability to perceive the surroundings in bad weather?
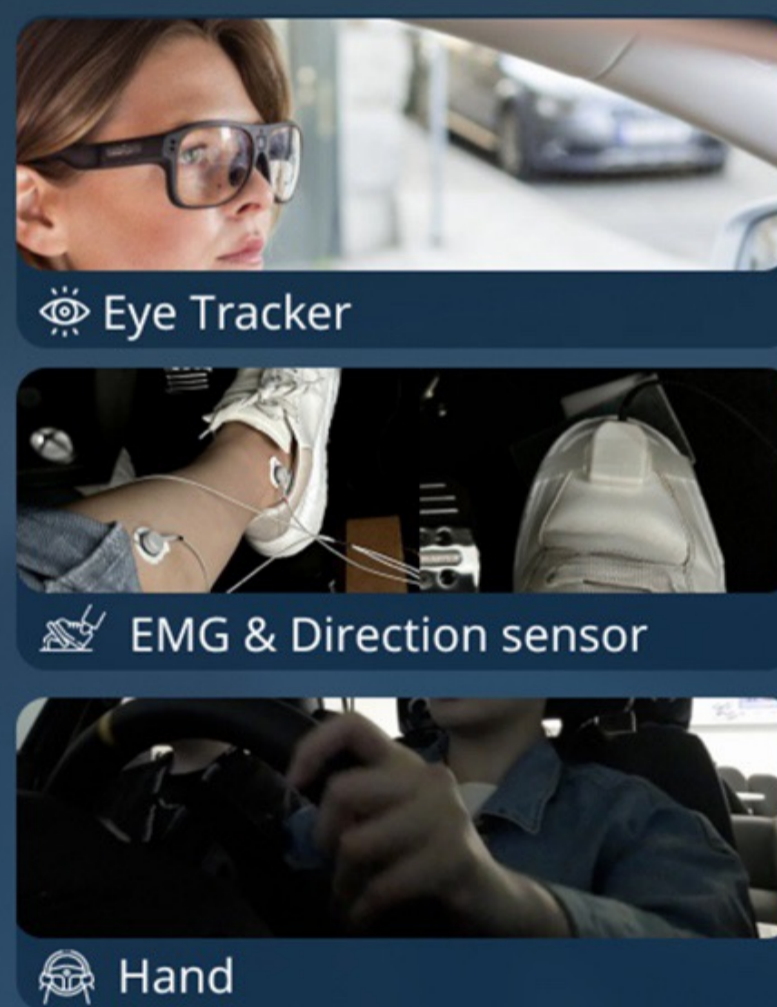
H4: In bad weather, AR-HUD navigation with a harpoon concept has benefits over solid fishbone for the driver to perceive the surroundings.
H5: These two AR-HUD navigation concepts have significantly different impacts on the user experience in bad weather.

EXPERIMENT DESIGN

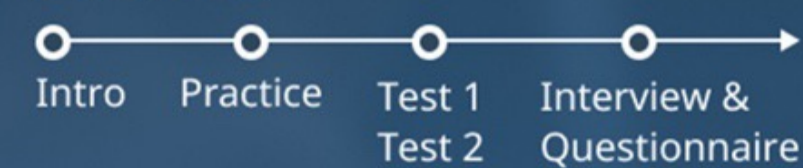### Environment setting

Virtual road - Foggy day
AR-HUD projection
Simulator   Testers   Experimenters

Prototype

Traditional navigation
↑ Go Straight 150ft   Next ↗

AR-HUD Solid fishbone

AR-HUD Harpoon

Measurement

👁 Eye Tracker

✍ EMG & Direction sensor

🖐 Hand

Process

Intro — Practice — Test 1 / Test 2 — Interview & Questionnaire

A total of 8 students, aged 20-35 years, participated in the experiment.

Test one aims to compare traditional and AR-HUD navigation in influencing driving behavior, which is related to Q1. Testers need to drive with three navigation concepts one by one without traffic. The second test compares the surrounding perception with two AR-HUD concepts, which would answer the Q2. Testers need to drive with the solid fishbone and harpoon and avoid hitting the stimulus.
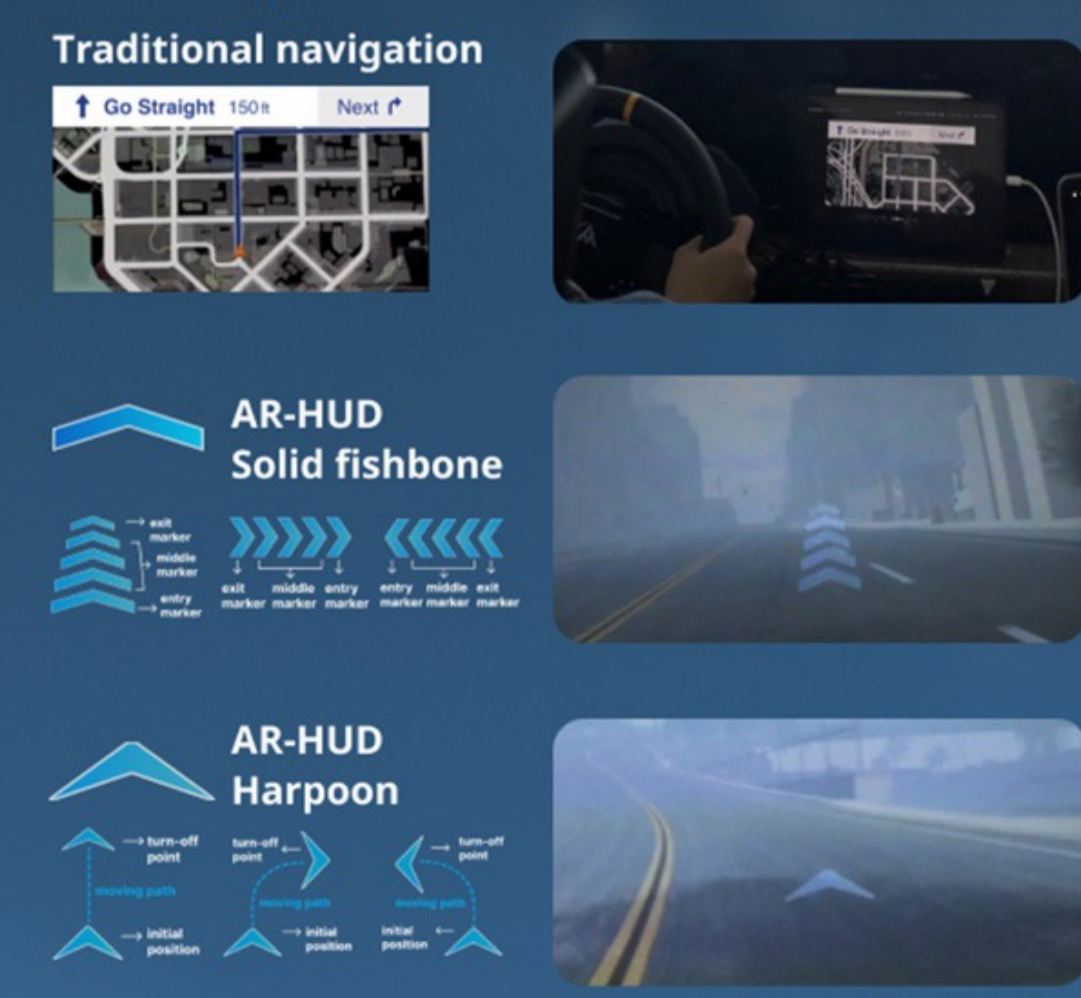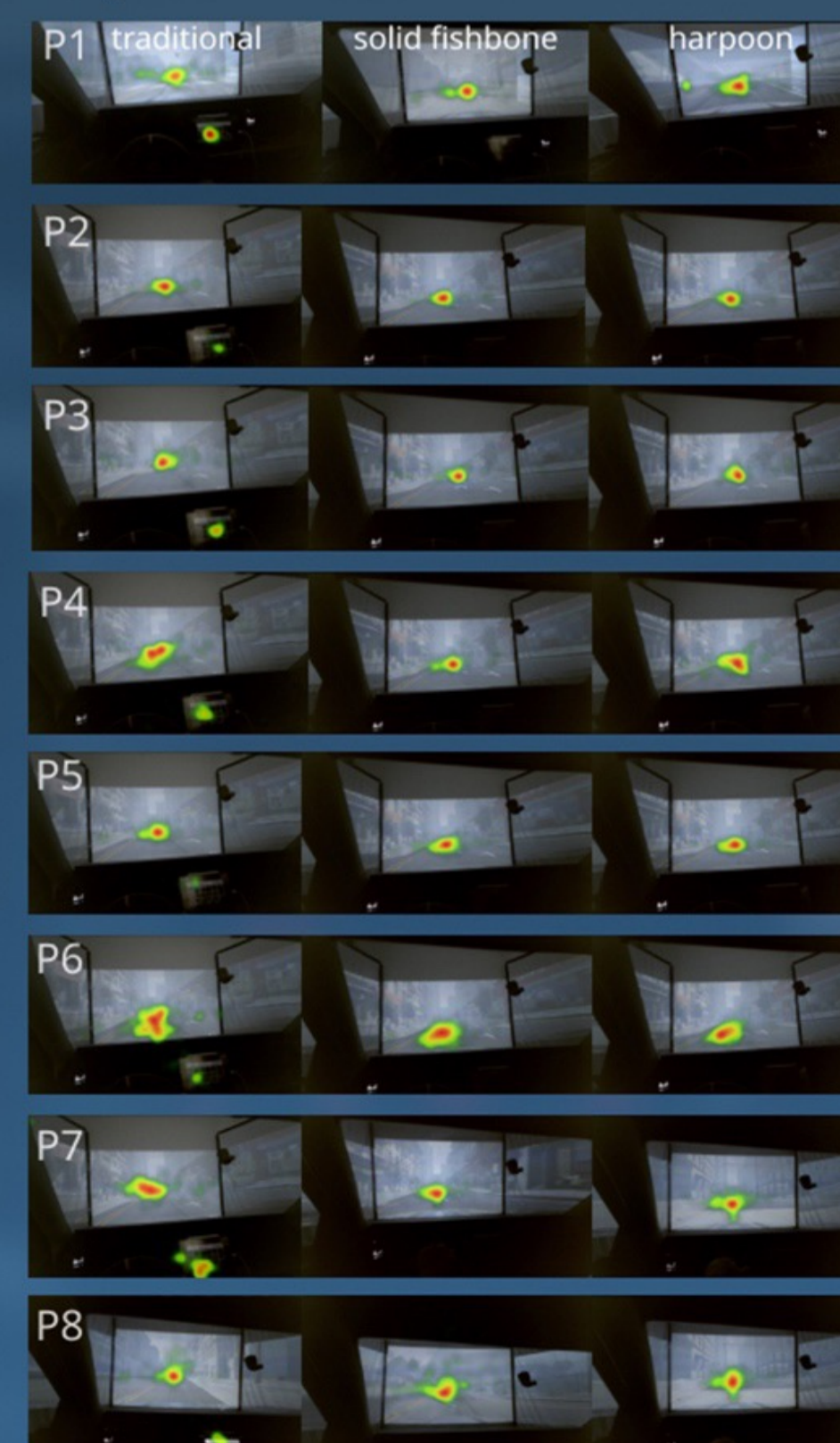
DATA ANALYSIS & FINDINGS

TEST 1 - Heat map & Fixation behavior

Finding 1:
Testers focus more on the road with AR-HUD navigation system

In each individual comparison, some of the green dots are on traditional navigation, meaning testers distracted some of their attention from traditional navigation.

P1 traditional   solid fishbone   harpoon
P2
P3
P4
P5
P6
P7
P8

Finding 2:
Harpoon concept is easier to understand, following the solid fishbone and traditional

Create the area of interest in three navigations and roads as highlighted.

Stimulus means the navigation guidance. Calculated the average fixation of stimulus, meaning the fixation time that testers spend in observing the navigation guidance. In comparison, the harpoon appears in the lowest (5 times), following the solid fishbone (2 times) and traditional (1 time).

No.	Number of fixations	Total number of stimulus	Average fixation of stimulus	Comparisons
P1	90	29	3.10	
	78	66	1.18	A(S) < A(H) < A(T)
	100	70	1.42	
P2	40	29	1.37	
	60	54	1.11	A(S) < A(H) < A(T)
	76	66	1.15	
P3	56	29	1.93	
	80	53	1.50	A(H) < A(S) < A(T)
	68	64	1.11	
P4	117	29	4.03	
	121	61	1.98	A(H) < A(S) < A(T)
	157	87	1.80	
P5	30	29	1.03	
	129	80	1.61	A(H) < A(H) < A(S)
	97	86	1.13	
P6	29	29	1.00	
	143	79	1.81	A(T) < A(S) < A(H)
	185	87	2.13	
P7	108	29	3.72	
	138	47	2.93	A(H) < A(S) < A(T)
	143	54	2.38	
P8	49	29	1.69	
	74	54	1.37	A(H) < A(S) < A(T)
	44	54	0.81	

TEST 2 - Heat map

Finding 3:
There is no clear difference between the heat map of the solid fishbone and harpoon

Some individual heat maps comparison that spread differently (e.g. P1,P3,P8) because of the Ai traffic flow.

P1 solid fishbone   harpoon
P2
P3
P4
P5
P6
P7
P8
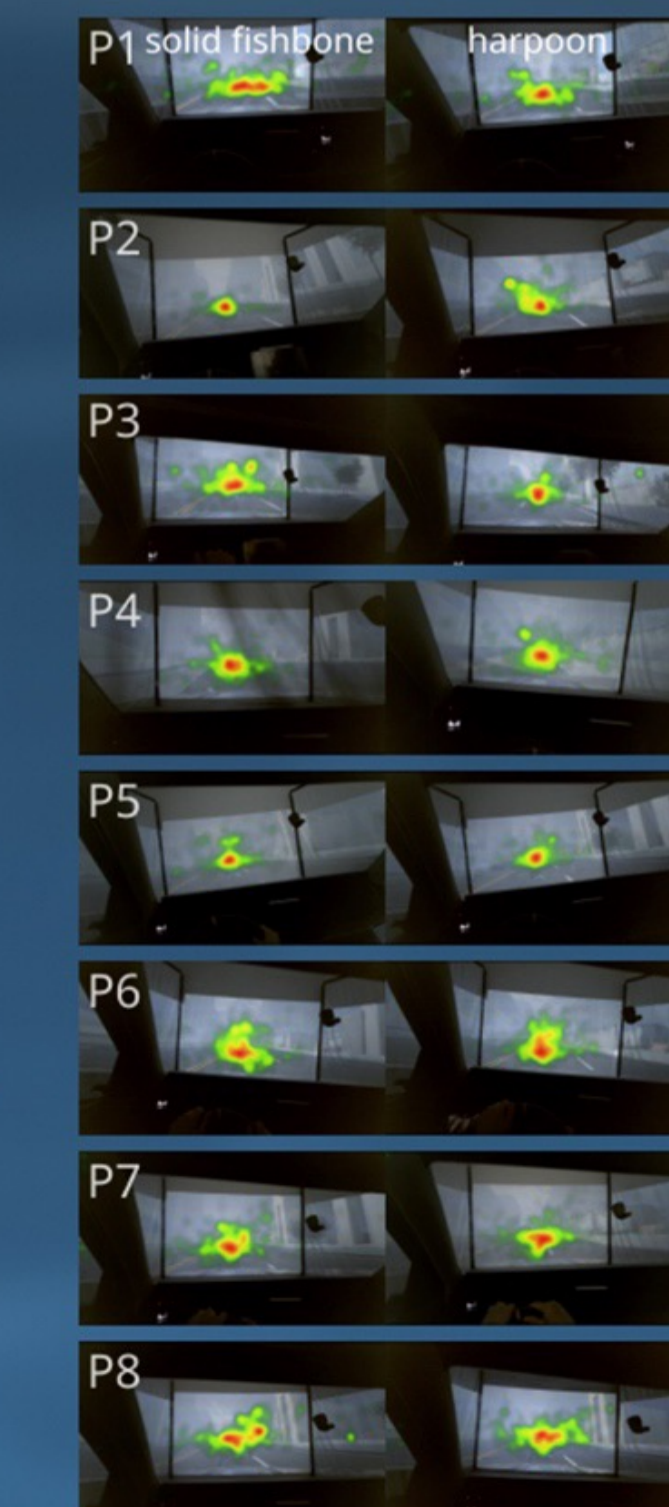
Perception Questionnaire

Finding 4:
Harpoon concept has slight advantages, especially for the 'comprehension' and 'road perception' aspect

No.	Question	M(SF)	M(H)
1	I can *understand* every directional sign that appears in this navigation very well	4.4	5.3
2	I can *react* well to each icon in a timely manner	4.0	4.5
3	I can *think* this navigation is reliable in foggy day	4.1	4.6
4	Using this navigation in foggy day does not affect my ability to *see the road*	3.5	4.5

Limitation & Improvement

1) Hard to observe some response behaviour and timing because the testers' personal habits and lack of specific points defining the beginning and end of the response, meaning this test can not answer the H3 accurately.
2) Remember the road, resulting they may do some pre-judgmental moves like braking early.
To refine this experiment, we could consider adding a specific operation as a metric to observe the response behavior. Also, adjusting the order of navigation shows.

CONCLUSION

For Q1, based on F1 and F2, AR-HUD navigation system does help drivers in bad weather in some ways compared to the tradition. For Q2, based on F3 and F4, the harpoon concept shows a slight benefit in perceiving the surroundings. However, the two AR-HUD navigation concepts do not have significantly different impacts on the user experience.