An XR eye-tracking investigation on the assessment of existing food habits

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Introduction and Related Work

Food systems contribute to at least 30% of global anthropogenic greenhouse gas (GHG) emissions annually [1]. To effectively lower these emissions, it is essential to understand individuals' food habits. Conventional approaches, such as food diaries and questionnaires, are commonly used but often introduce biases and do not effectively capture the complexities of individuals' food choices [2]. Recent advancements in XR technologies, such as virtual reality (VR), augmented reality (AR), and mixed reality (MR), have revolutionized food selection studies by allowing controlled experiments to take place in highly realistic virtual settings [3]. These technologies, particularly when combined with eye-tracking metrics, offer more objective insights into individuals' cognitive and emotional responses to food [4]. This investigation addresses existing gaps of XR studies on sustainable practices by combining traditional questionnaires with XR eye-tracking. It creates immersive scenarios to better understand diverse food choices and allows for rapid adjustments, offering deeper insights into how various factors shape food preferences.

Methodology

This study leverages eye-tracking analysis in virtual reality (VR) to evaluate participant engagement by focusing on key metrics such as gaze direction, duration, and fixation frequency. By refining thresholds for gaze duration, the study differentiates between brief glances and significant interactions. Utilizing XR hardware and the OpenXR framework, participants engage with virtual food items in an VR setting while their gaze behaviors are tracked. Gaze points, durations, and fixation locations are visualized using heatmaps, and quaternion rotation data is converted to Euler coordinates for more accurate analysis of gaze direction.

Experimental Setup

The flowchart (Fig. 1) outlines the methodology used to investigate the connection between visual attention and dietary choices. In a VR environment, participants' food preferences are evaluated as various virtual food options are presented on a table in an immersive 3D format. This setup is specifically designed for eye-tracking research, allowing for detailed observation of interactions with different food items. Eye-tracking data is gathered through Unity and the Oculus OVR Eye Gaze component, capturing participants' gaze interactions with virtual foods. The system records gaze fixations and processes key metrics like direction, duration, and fixation points, which are then analyzed alongside questionnaire responses to better understand food preferences. The results are visualized using 3D heatmaps to identify high-interest areas, revealing which food items draw the most attention.

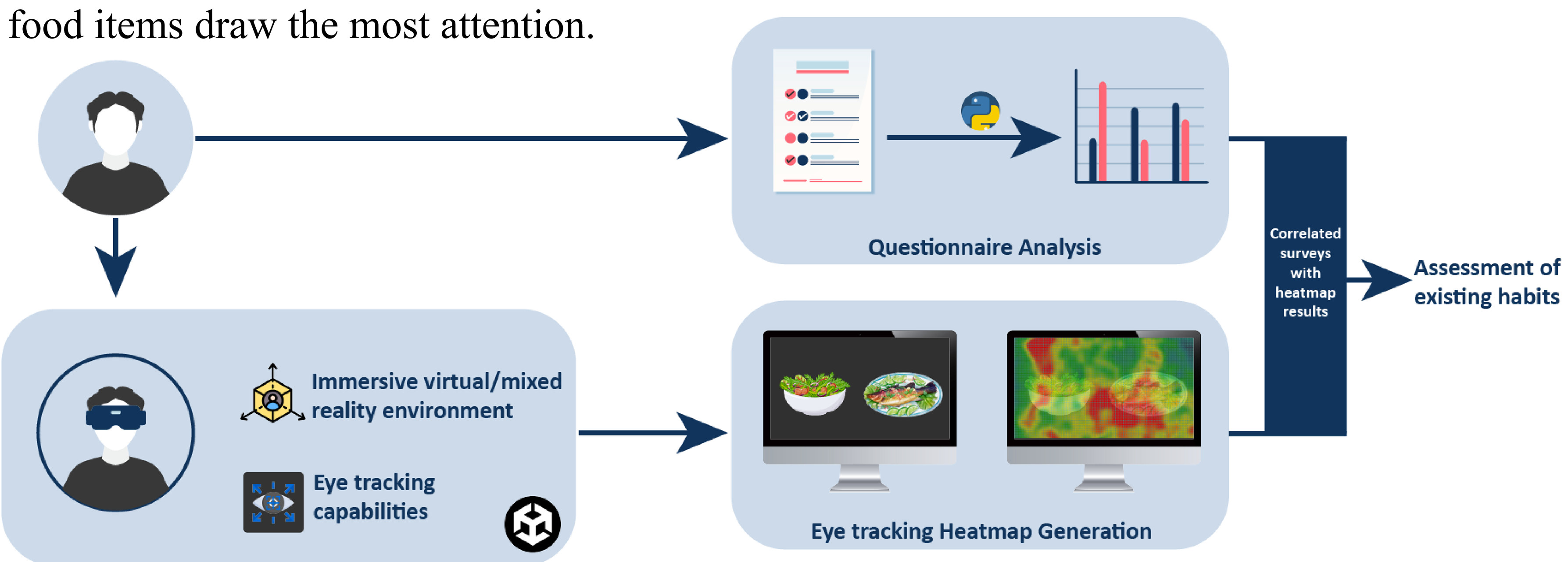


Figure 1. Extended Reality-Based Behavioral Analysis Flowchart: Identifying Dietary Choices through Eye-Tracking, Heatmaps and Data Analysis

Assessment of Participants

The study surveyed 114 participants, revealing diverse food preferences and notable differences in gender, BMI, and health concerns among carnivores, vegetarians, and vegans. The carnivorous group had more males and higher obesity rates, highlighting gender and cultural influences, as well as the benefits of plant-based diets. Table I provides a brief overview of food choices of diverse demographic clusters. Additionally, taste came out as the top factor for individuals when selecting food, followed by health, cost, convenience, and freshness (Fig. 2).

Table 1. Comparison of dietary groups across various categories

Category	Vegetarians	Omnivorous	Carnivorous
Age Groups			
18-24	28.57%	6.25%	0%
25-34	14.29%	23.96%	14.29%
35-44	28.57%	56.25%	57.14%
45-54	0%	7.29%	0%
55-64	0%	3.13%	14.29%
65+	28.57%	3.13%	14.29%
Gender			
Male	28.57%	37.5%	71.43%
Female	71.43%	60.42%	28.57%
Non-binary	0%	2.08%	0%
Prefer not to say	0%	2.08%	0%
BMI			
Underweight	0%	2.08%	0%
Normal Weight	57.14%	63.54%	28.57%
Overweight	42.86%	28.13%	71.43%
Obese	0%	6.25%	0%
Environmental Impact			
Very Low	0%	13.54%	14.29%
Low	0%	17.71%	28.57%
Moderate	42.86%	46.88%	42.86%
High	42.86%	19.79%	14.29%
Very High	14.29%	2.08%	0%
Health Concerns			
Very Low	0%	4.12%	0%
Low	0%	7.22%	42.86%
Moderate	57.14%	38.14%	42.86%
High	28.57%	42.27%	14.29%
Very High	14.29%	8.25%	0%
Ethical Concerns			
Yes	71.43%	27.08%	0%
No	28.57%	72.92%	100%

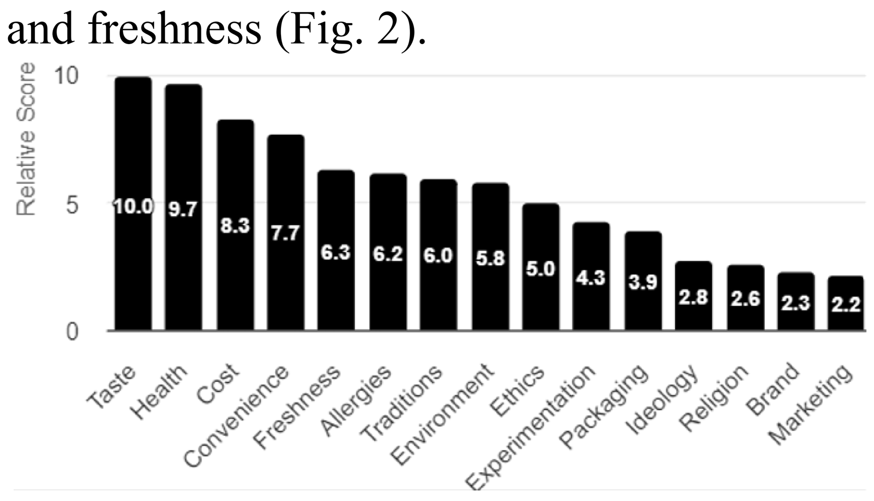


Figure 2. Key Factors affecting food habits of dietary groups

Demonstration

Immersive Virtual Reality (VR) content was developed to analyze correlations between participants' eye-gazes and factors affecting food choices (Fig. 3). User interactions, such as eye tracking, clicks, and gaze duration, were meticulously tracked in the VR setting.

Figure 3. VR Environment Setting and food scenarios

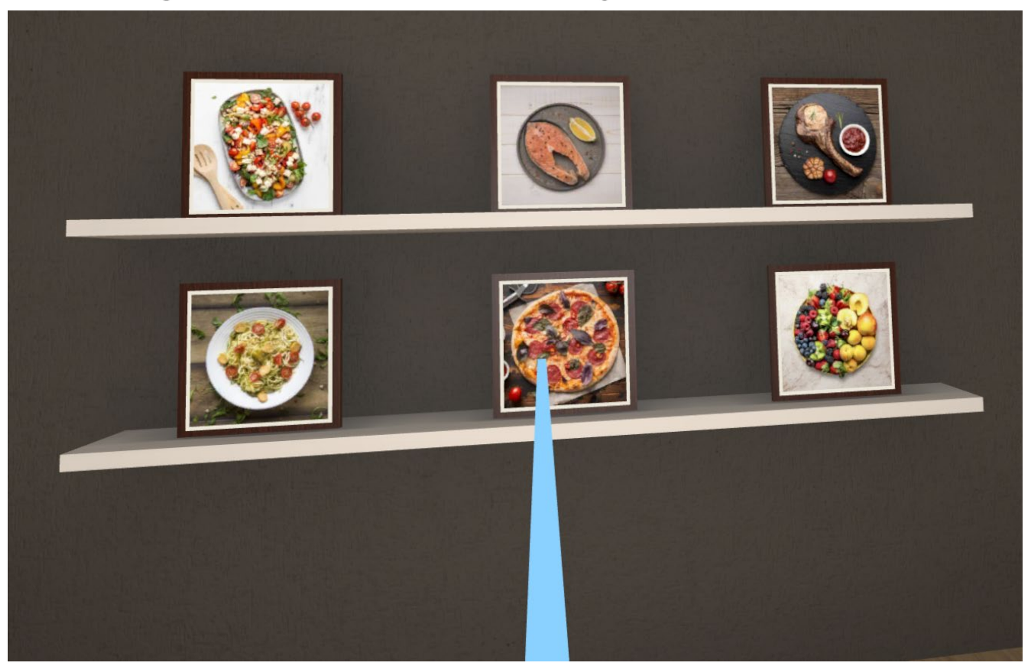


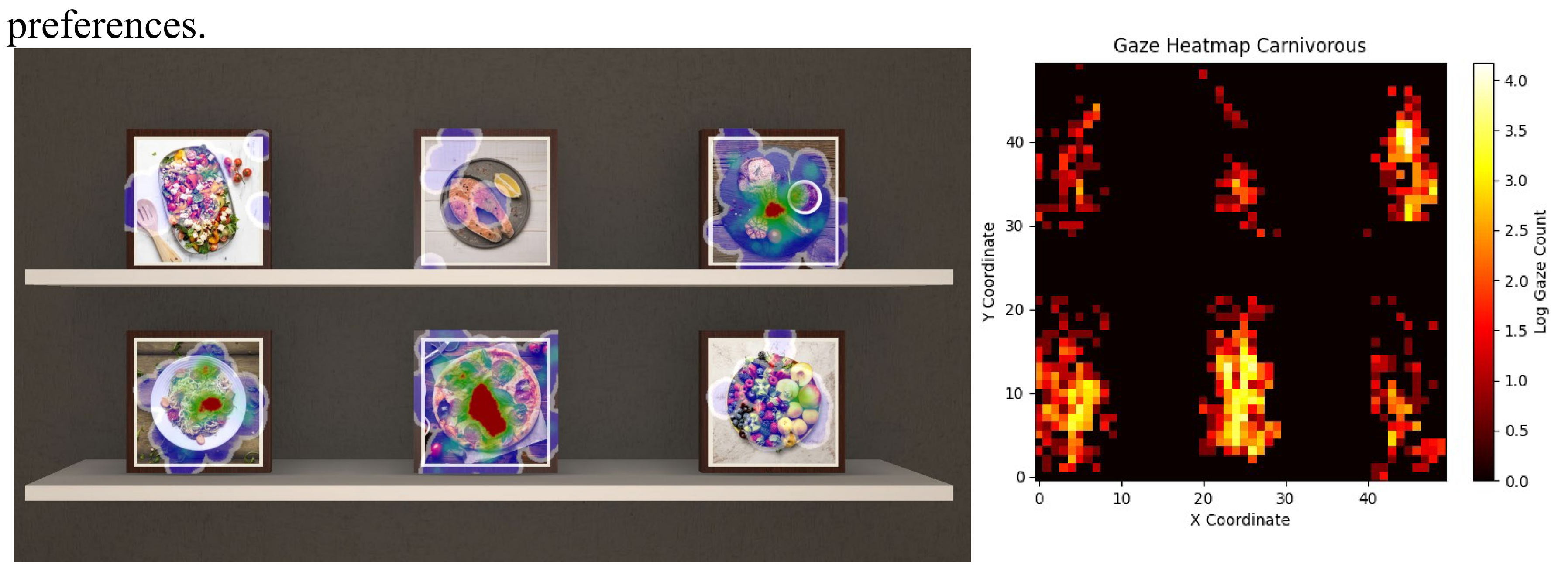
Table 2. Results of Number of Gazes, Total, Max, and Average Gaze Duration per Food Scenario at a sampling ratio of f = 50 Hz and minimum gaze fixation > 0.15 s

Group	Scenario	Count	Total Gaze (s)	Avg (s)	Max (s)
Vegetarian	Fish	13	9.59	0.74	2.44
	Pasta	14	10.56	0.75	1.68
	Pizza	15	10.06	0.67	2.44
	Steak	8	3.48	0.44	0.74
	Fruits	11	10.34	0.94	0.74
	Salad	18	16.17	0.9	2.34
Omnivorous	Fish	10	4.00	0.40	0.88
	Pasta	2	1.08	0.54	0.58
	Pizza	8	4.12	0.52	1.04
	Steak	11	11.96	1.087	3.32
	Fruits	7	4.58	0.65	1.88
	Salad	3	2.02	0.67	0.90
Carnivorous	Fish	5	1.94	0.39	0.78
	Pasta	13	13.28	1.02	4.48
	Pizza	12	24.84	2.07	9.50
	Steak	5	12.48	2.50	6.28
	Fruits	6	3.96	0.66	1.34
	Salad	3	2.22	0.74	1.56

Table 2 presents the gaze metrics for participants with different dietary preferences (vegetarian, omnivorous, and carnivorous) across various food scenarios. Vegetarians spent more time focusing on sustainable food options, such as salad and fruits, with the highest total gaze times recorded for these items. Carnivorous participants, by contrast, showed a strong preference for meat-based scenarios, spending more time on steak and pizza, reflecting their dietary habits. Omnivorous participants displayed a more balanced engagement across both plant-based and meat options.

Heatmaps generated within the VR environment (Fig. 4) for an carnivorous participant highlighted areas of concentrated visual attention, offering insights into individual visual engagement with specific food scenarios, highlights how the VR environment successfully aligns user engagement with individual dietary preferences.

Figure 4. Left: Visual attention heatmaps generated within the VR environment for carnivorous participant. **Right**: 2D heatmaps analysis for carnivorous participant



Conclusion and future studies

The VR environment analysis confirmed that participants with sustainable dietary habits spent more time engaging with images of sustainable food, whereas those with a preference for meat gravitated toward meat-based scenarios. The true potential of this tool lies in its ability to uncover deeper behavioral insights. Future research will investigate additional factors like selection patterns and physiological responses (such as pupil dilation and heart rate) to further enhance the XR tool's functionality. Expanding on these findings, upcoming studies will create new MR scenarios through projected experiences addressing a wider spectrum of consumer behaviors, including those related to the circular economy and climate resilience (Fig 5), aiming to collect data on how targeted campaigns can effectively drive a shift towards sustainability, ultimately supporting societal acceptance and the success of policies that encourage sustainable practices.

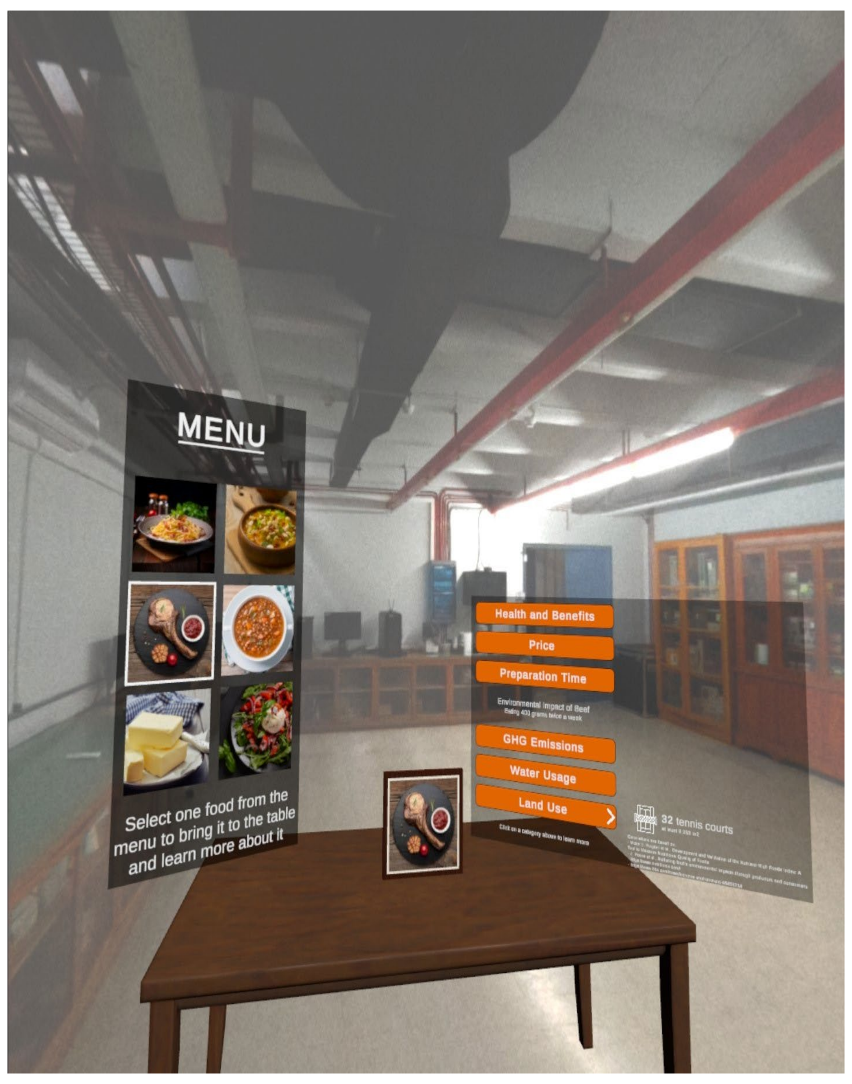


Figure 5. Mixed Reality Environment Setting with Data Storytelling Visuals

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