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Visual Perception of Roadside Advertisements by Diverse Urban Mobility System

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ABSTRACT

In the cities of today, individuals have to constantly visually perceive their surroundings in order to move, be safe, and know where they are going. Advertisements have to grab people's attention even though there are plenty of other things to look at. This research investigates the responses of people to the billboard advertisements while they are on the move with an emphasis on what appeals both to their eyes and their minds. The paper examines the influence of different modes of movement, walking, driving or taking a bus, on people's visual perception and recall of various roadside adverts. This study wants to help advertisers, planners, and designers know how speed and where an ad is making a difference in real life. It also helps us know more about how people see things while moving. The study used several methods for large-scale experiments. People went through virtual reality simulations that copied a real city road. In the study, people moved in different controlled ways. Mobility mode and spatial location have a substantial impact on the attention and processing of visual information, with the study concluding that recall effectiveness can be improved by matching movement patterns and ad placement, while proposing further confirmation through real-world urban environment testing in the future.

Keywords: Visual perception, Urban mobility, Advertising

INTRODUCTION

Cities are always bustling and vibrant with information, where individuals are always exposed with influx of visual stimuli competing to direct, inform or persuade them (Chana et al., 2023; Ye et al., 2022). Amongst this deluge of stimuli, outdoor advertisements provide a robust and relatively constant force immersing the individuals and influencing the commercial and cultural fabric of the contemporary city (Jin et al., 2025). As urban areas grow and commercial activity increases, these surfaces must vie for human attention, within increasingly intricate perceptual field, teeming with architecture, traffic, signage, advertise, and digital screens (Tekin Yücesoy, 2025).

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The Evolution of Outdoor Communication

The Indian outdoor advertising sector is largely unregulated, and this is reflected in the disproportionate degree of visual clutter and almost complete disregard for legibility parameters (Iveson, 2012). Traditionally, the location of these hoardings has been based on intuition or market-driven parameters rather than systematic studies of human perception (Halim et al., 2023). Although these advertisements are visually prominent components of the streetscape, structured methods for assessing their communicative effectiveness are relatively rare (Jin et al., 2025). In the past, research has primarily focused on driver attention and highway safety, largely ignoring distinct perceptual needs and opportunities presented by pedestrians and public transport passengers, in many Indian cities, constitute majority of road users (Sethulakshmi & Mohan, 2025).

The Dynamics of Urban Mobility

The mechanics of how people see advertisements 'on the move', have come to constitute an area of critical interest for design and planning (Lim et al., 2024). What a pedestrian might notice sauntering along at a leisurely pace is fundamentally different from what a driver has the bandwidth to notice at high speeds or a bus passenger can see from an elevated vantage point (Chana et al., 2023; Lim et al., 2024). Traditional methods of evaluation, be it static analysis of visibility or post exposure recall surveys, fail to capture either the dynamic nature of movement in cities or the cognitive limitation of perception-on-the-move (Lou et al., 2024). If these situational perceptual differences are not considered, advertising might be ill, advised of the true visual behavior of the commuting public, and thus, it may eventually fail to connect with them (Iveson, 2012; Schrammel et al., 2011).

Theoretical Underpinnings of Visual Attention

To connect the design Intent with user experience, the study takes psychological and spatial theories as its major reference, these are briefly explained as follows:

Visual Saliency Theory

This posits that certain features (e.g. contrast in color, luminance and orientation) create perceptual 'hotspots' that the human eye is automatically drawn towards (Kienzle et al., 2006). To be seen among so many other things in a visually cluttered city, a billboard needs to have enough features of sufficient salience so that it is not visually overpowered by the surrounding architectural texture and traffic (Ullah et al., 2020).

Cognitive Load Theory (CLT): According to CLT, the working memory of humans when processing information can only accommodate a limited number of items at a time (Plass et al., 2010). Hence, if a billboard layout with the "too many words" sermon is complicated or "washed in colors," viewers won't be able to figure it out within the microseconds of exposure time if they are in a moving car (Jordan et al., 2020; Plass et al., 2010).

Signal Detection Theory (SDT): SDT is a tool that helps in assessing how much of the "signal", the ad, an observer is able to separate from the "noise" of a chaotic urban environment (Abdi, n.d.). It is the SDT which has to be considered when one is trying to understand legibility thresholds and the minimum contrast requirements necessary for almost instantaneous recognition in motion (Cradit et al., 1994).

Location Theory: While this is traditionally used in urban planning, this theory provides insights as to how proximity and angles (i.e. proximity to pedestrian path or road curvature and alignment,) influence visibility and behavioral change (Cian et al., 2015; Kwon et al., 2024).

The Role of Virtual Reality in Perceptual Research

Recent advancements in Virtual Reality (VR) and eye-tracking technologies have opened up new avenues for simulating real-world viewing environments within controlled laboratory experiments (Adhanom et al., 2023). VR allows for recreating city streets with a fidelity high enough and systematizing variations of different billboard attributes to observe gaze patterns with a level of freedom and control that is simply not possible in the field (Schmälzle et al., 2023). Unlike traditional field or laboratory studies, VR allows for uniformity in environmental conditions, making it possible to isolate effects of factors such as distance, speed, and angle of approach (Adhanom et al., 2023; Schmälzle et al., 2023). This technological testbed allows for "ecological validity" i.e. the results garnered in a virtual environment will reliably generalize to the real-world perceptual behaviour (Parsons, 2011).

Research Objectives and Scope

This research attempts to bridge the above-mentioned research gaps by determining the relationship between typographic variables and mobility-based eye tracking within a controlled boundary of VR Environment and a particular segment of Biswa Bangla Sarani, Kolkata was selected as the study area due to its rich commercial frontage with a variety of different typographic stimulus & different types of billboards (Kim & Park, 2020; Schmälzle et al., 2023). The "digital twin" of the corridor is used to simulate three separate viewing conditions – pedestrian, car, and bus (Jin et al., 2025; Liu et al., 2024). By identifying mobility-specific patterns of fixation duration and gaze path distribution, this research hopes to provide evidence-based inputs to the design of more human-centred outdoor communication systems that are mindful of the issues of visibility, clarity and urban aesthetics (Chana et al., 2023; Simpson, 2021).

METHODOLOGY

This study employed an immersive, within-subject experimental design to examine how urban mobility conditions influence the communicative and ergonomic performance of roadside advertisements. The research tried to separate the effects of speed and viewpoint height on the perception of billboards by using spatial simulation together with conditions of controlled movement, all while maintaining control over the graphic variables.

Figure 1 : (a) study road study stretch (b) Digital twin development process.

Digital Twin Development and Site Selection

The experiment's environment was based on a "digital twin" of a specific example of a rich urban corridor – Biswa Bangla Sarani, Kolkata (*Figure 1*). This was selected due to its rich commercial frontage, with different types of billboards as well as the researcher's familiarity with the locality, which ensured contextual sensitivity during the modelling stage. The geometrical modelling process for the virtual street is done in SketchUp and Blender, based on geometry, distances, and spatial proportions collected from Google Earth and Apple Maps. The resulting models are imported into Unity 6.1, where original, realistic textures of facades and environmental parameters are incorporated for integration into the platform. Then, Unity-enabled virtual camera rigs are inserted into the 3D vehicle models at select eye-level perspectives of pedestrians, cars and buses to replicate realistic viewpoints (*Figure 2*).

Figure 2 : (a) Actual image (b) Digital twin modelling.

Simulation Scenarios and Attributes

To isolate mobility effects, all graphic attributes were standardized. Helvetica typeface, black text on yellow background, was used for maximal luminance contrast. Message length and hierarchy were structurally balanced across boards. Message sets were rotated among participants while maintaining equivalent complexity between sets, thereby removing the potential for memorization bias without changing semantic difficulty. Thirty-one participants (n = 31), with normal or corrected to normal vision, were recruited. Individuals with vestibular sensitivity were excluded to maintain the stability of VR immersion. All the participants had 3 different movement modes in a same street environment: Pedestrian Mode (an approximate pedestrian speed of 3.7 km/h from a first-person perspective at eye level), Car Mode (an approximate driving speed of 17 km/h from a first-person perspective in a seated position as a driver), and Bus Mode (an approximate bus speed of 13 km/h from a first-person perspective in an elevated seated position as a bus passenger) (*Figure* 3).

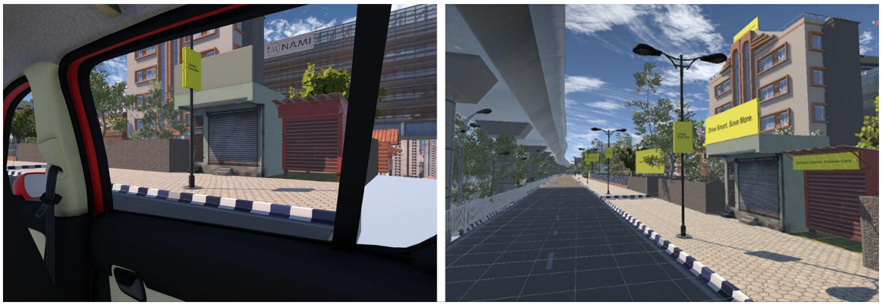

Figure 3 : (a) Car mode (b)Pedestrian mode modelled in Unity 6.1.

Speed and viewing height were the only variables used in this experiment, and the environment was controlled across the conditions. In scenario movement path was kept on script to match exposure duration and movement trajectory. To minimize the learning curve, scenario order was randomized for each participant.

Data Collection and Participant Protocol

The experiment was administered using a predetermined protocol. First, participants completed a baseline survey that included a short demographic and mobility questionnaire (including habitual commute mode and prior VR experience). Later, in the immersive exposure, the participants wearing only a VR headset experienced all three scenarios in random order. Furthermore, after each scenario, participants were required to evaluate their perceptions of the fourteen billboards by giving their ratings on two 5, point Likert scales: Information Effectiveness (1 = Very Ineffective, 5 = Highly Effective), Viewing Comfort (1 = Very Uncomfortable, 5 = Very Comfortable). The higher scores represent more successful perceptual outcomes. A brief recall task was administered after each scene to provide an additional confirmation of the Information Effectiveness ratings.

Analytical Framework

Data have been aggregated at the billboard and typology level. The primary analysis was conducted by comparing each billboard's performance against different mobility modes and the typology. Information Effectiveness and

Viewing Comfort were individually assessed and also together, the aim being to study how communicative clarity and ergonomic alignment are related under different motion constraints. This approach makes it possible to accurately control a nature setting, but still, measure billboard performance in kinetic urban environments.

RESULTS

Outdoor advertising in cities is highly dependent on how people move around and the position of the eye level with the billboard that accompanies it, experimental data analysis suggests. The next sections discuss the results from the user testing phase which required 31 participants. The overall outcome of the experiment has been illustrated in the tables below *Table 1* and *Table 2*.

Table 1 : Aggregate performance by billboard type and mobility mode (31 participants).

Information Effectiveness				Viewing Comfort			
Billboard Type	**Pedestrian**	**Car**	**Bus**	**Billboard Type**	**Pedestrian**	**Car**	**Bus**
Roadside	4.1	3.8	4.3	Roadside	3.7	4	4.1
Pole-Mounted	3.95	3.1	3.9	Pole-Mounted	3.9	2.6	3.4
Overhead	3.7	4.2	4.4	Overhead	2.9	3.8	4.2

Table 2 : Detailed billboard-level results (mean across 31 participants).

Information Effectiveness				Viewing Comfort			
S. No.	**Pedestrian**	**Car**	**Bus**	**S. No.**	**Pedestrian**	**Car**	**Bus**
1	3.6	4.2	4.3	**1**	3.6	4.2	4.3
2	3.7	3	3.8	**2**	3.7	3	3.8
3	3.55	4.1	4.2	**3**	3.55	4.1	4.2
4	4.25	3.2	3.9	**4**	4.25	3.2	3.9
5	4.15	3.1	3.9	**5**	4.15	3.1	3.9
6	4.3	4.4	4.4	**6**	4.3	4.4	4.4
7	4.05	3	3.8	**7**	4.05	3	3.8
8	3.9	3	3.7	**8**	3.9	3	3.7
9	4.2	3.9	4.3	**9**	4.2	3.9	4.3
10	3.75	4.3	4.5	**10**	3.75	4.3	4.5
11	3.85	3.1	3.8	**11**	3.85	3.1	3.8
12	3.65	4.3	4.4	**12**	3.65	4.3	4.4
13	4.45	4.3	4.5	**13**	4.45	4.3	4.5
14	4.5	4.4	4.6	**14**	4.5	4.4	4.6

Mode-Specific Findings

Pedestrian Scenario

As far as pedestrians are concerned, the roadside billboards were at the top of the list of the highest Information Effectiveness scores (4.10). This can be interpreted as the proximity that helped the respondents in the airline scene comprehension of the first ad significantly. Popular pole, polarity, billboards are almost as close (3.95), whereas the effects of overhead billboards are slightly lower (3.70), presumably pedestrians have an unconventional viewing angle to them when they are walking. The latter is presumably unconscious that the visual angle is unusual for pedestrians as such them going on the move. However, Viewing Comfort followed a different trend: pole-mounted billboards produce a relatively high comfort level (3.90), roadside billboards moderate comfort (3.70), and overhead billboards with the lowest comfort level (2.90), indicating that although overhead billboards are still communicative under walking conditions, they tend to cause more ergonomic or visual accommodation strain. For pedestrians, the recall performance generally matched the Information Effectiveness rating indicating that slower speed of movements enables a deeper level of semantic processing with information.

Car Scenario

The differences between types of billboards were greatest in the car mode. Compared to pedestrian mode, the Information Effectiveness score is highest for the overhead billboards (IE-Car: 4.20), followed by the roadside boards (IE-Car: 3.80), and plummeting in the pole-mounted boards (IE-Car: 3.10). Viewing Comfort in the car mode follows a similar trend, as the pole mode, un-ergonomically positioned at car speeds, received a poor comfort score (VC-Car: 2.60). The overhead in comparison maintains a relatively high level of comfort (VC-Car: 3.80), but again due to the alignment between the car's intrinsic gaze forward and the overhead. As a result, the relationship between Information Effectiveness and Viewing Comfort is much more tightly bound in car mode than in pedestrian mode, as it appears that the discomfort in higher speeds translates more directly to communicative effectiveness. Recall performance dropped overall in car mode, particularly in the recall of secondary textual elements.

Bus Scenario

The bus mode had the best performance on Information Effectiveness and Viewing Comfort. Overhead billboards got the highest score for Information Effectiveness (4.35), with roadside billboards getting a similar score (4.25), and pole-mounted billboards doing better than in car mode (3.85). For Viewing Comfort, every typology scored the highest in bus mode, with overhead billboards at 4.15, roadside billboards at 4.10, and pole-mounted billboards at 3.40. Combination of a higher viewpoint and a medium speed seems to be a good mix as they compensate for the duration and the quality of the view of billboards, respectively. People felt more positive about the information and the comfort of the billboards when they were in cars. This implies that the elements became more closely connected owing to the movement.

DISCUSSION

The experiments results reveal a significant difference between the current marketing of billboards and what people actually perceive who travel through the city. In fact, the objective and subjective data combined in a section that focuses on the interrelation of movement, spatial ergonomics, and mental activity.

The Impact of Viewpoint Height on Ergonomics and Clarity

The most important finding of this study is that height of vantage point, as a variable, is the primary determinant for both readability and comfort.

Pedestrian Comfort: Pedestrian ratings of comfort on foot turned out to be the most diverse. Although the walking speed gives sufficient time for exposure, some billboards were rated as less comfortable even though the Information Effectiveness score did not decrease. This suggests that being in harmony with the natural posture is at least as important on the ground level. At pedestrian level, the typical gaze direction is straight ahead and slightly downward. If the advertisements are not within this area of attention, one has to change the posture or the angle of the neck to look at them, which lowers Comfort. Even if the message is clear enough, the physical misalignment causes a little resistance to perception. So, to a large extent, pedestrian vulnerability is an ergonomic issue rather than a cognitive one.

Elevation Advantage: In contrast, the results at the bus situation showed the top overall scores for both Information Effectiveness and Viewing Comfort. From a raised lead, it seemed that one would get the benefits of both improving the line of sightal alignment and decreasing angular distortion, and a moderate speed gave a balanced window of exposure for message acquisition. These results imply that billboard installations might be unwittingly favouring the elevated perspective, thus making the ground, level one less effective.

The Viewing Comfort–Information Effectiveness Relationship: A significant finding of the study is that the two dimensions, Information Effectiveness and Viewing Comfort, do not necessarily depend on each other. When people are walking, some outdoor advertisements were quite effective in terms of communication but less comfortable to the eyes. On the other hand, some boards were physically convenient but failed to communicate well in vehicle modes. This separation indicates that clarity and comfort are somewhat different perceptual aspects that are still related. Nevertheless, in car mode, the association between the two variables became stronger. We found that the decline in Information Effectiveness was less often paired with Lower Viewing Comfort.

Cognitive Load and Content Simplification: Speed of movement places a temporal constraint on information intake. This study gives us a new appreciation for how transport mode shifts the “window of opportunity” for message reception.

Speed vs. Comprehension: Even with a significant background, to, text contrast, the Information Effectiveness in a car at 17 km/h fell apart for particular types of billboards. On the basis of recall responses, those people could get the main headlines but usually didn’t remember the secondary content (the time/place of the event, the advertisers name). This is basically a confirmation of Cognitive Load Theory: semantic processing is limited by working memory, and working memory is limited by the rate of movement. The viewers in car mode have to share their working memory between driving the car and watching the ad, which is why the resultant processing is only at the surface level. From the bus (13 km/h) perspective, Information Effectiveness was better than in car mode, which suggests that a combination of moderate speed and a higher level of view mitigated cognitive compression. Walking mode not only enhanced higher, level semantic processing, but it also exposed the user to greater ergonomic variations.

Signal Detection: According to Signal Detection Theory, the effectiveness of a billboard is largely determined by its capacity to be noticed as a perceptual “signal” among various urban “disturbances.” Various billboard types with high brightness contrast have been found to show decreased Information Effectiveness in vehicular contexts. That is to say, the clearness of a signal is influenced by factors in addition to its being very eye, catching. It also depends on how well the signal matches with the direction of people’s gaze and how long they can look at it. Understanding becomes more difficult if the angle is not right or there is less time for seeing it. A billboard is deemed to be of lesser value if it cannot present its message to the viewer quickly. That is why it is equally important to synchronize a thing with people’s movement as it is to make it clear to read.

What Urban Designers Should Do

As the study was conducted in a VR environment, there are a few practical implications. In spaces where people move around in numerous ways (for example, walking people and vehicles), dual, height strategies are crucial for billboards to stay visible and effective for different groups of people. Billboards should be positioned in an ergonomically way, just along the natural gaze path to get the most out of visibility and comprehension. Density of content should be mode-dependent, communicating concise and highly legible information in vehicular scenarios in the overhead billboard format, but allowing for more detailed content in pedestrian contexts where the information can be viewed for longer periods of time. Finally, a high contrast visual palette is essential to preserving visibility at a distance, particularly under motion, albeit not without the proper placement and alignment.

CONCLUSION

This research proves that the mobility context fundamentally influences the effectiveness of urban billboards. The experiment shows that, even when all billboard messages conform to best practices of typography—keeping the typeface constant, maximizing luminance contrast, and closely controlling message length—Information Effectiveness and Viewing Comfort vary dramatically when pedestrians, cars and buses are taken into consideration. The results reinforce that what is measured to be billboard performance is not a graphic design challenge but a spatial-perceptual phenomenon formed by speed, height and the alignment with the natural gaze.

Additionally, the optimal perceptual alignment might be a moderate speed combined with an elevated vantage point, since the most consistent positive results were found in the bus condition. The car condition put the biggest limits on Information Effectiveness. This term represents cognition that is limited, time that is restricted, and shortened exposure time all combined. The pedestrian condition gave the biggest semantic processing of the messages but a significant ergonomic sensitivity on the messages. Indicating that comfort and clarity are not always coupled at the ground level. One important finding from the study is that Viewing Comfort and Information Effectiveness are biologically related but different dimensions of response. In fast environments, poor ergonomics affects communication more compared to slow environments, where viewers can endure some discomfort without much communicative harm. These contradict the assumption of universal norms for billboard designs. In fact, they support a mobile, responsive framework where placement height, spatial orientation, and content density are adapted to the most dominant and flowing modes of transport.

The use of immersive digital twin simulation also reveals the potential of Virtual Reality as a diagnostic pre, installation testing tool for the designers and policymakers to consider. By integrating empirical evaluation, which is evidence, based and people, oriented, urban communication planning can help designers and policymakers to come up with more appropriate advertising systems for today's urban life.

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