

Revolutionizing Formula 1 Broadcasting: Unveiling the Impact of Personalized Virtual Advertising on Brand Recall through eye-tracking

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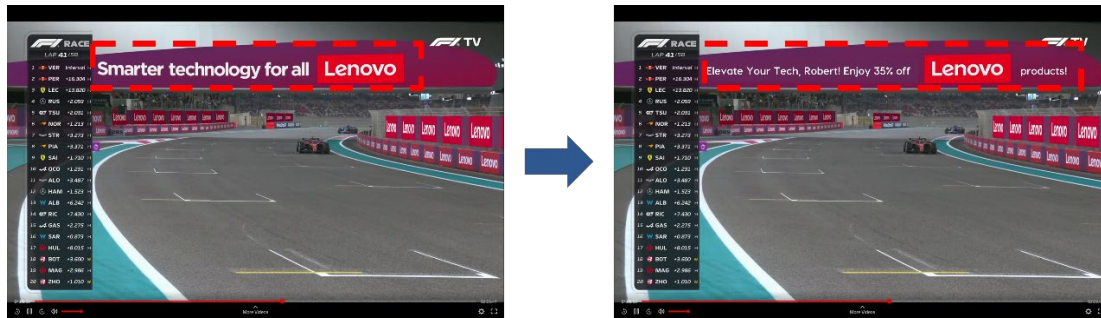
1. Introduction

Virtual Advertising, first introduced in the mid-1990s in the USA (Sander & Altobelli, 2011; Porter, 2022; Leadsom, 2023a; Goldman, 2023), has been significantly advanced by companies such as Supponor, Vizrt, HEGO, Broadcast Virtual, UniqFEED and AE Live, which are at the forefront of its development. This technology allows for the real-time replacement of physical perimeter boards with virtual ones, presenting targeted ads to local broadcast audiences (Supponor, 2020; Turner & Cusumano, 2000; Burgi, 1997). In-person spectators do not see these virtual advertisements, as they are overlaid only on the broadcasted version of the event (Cianfrone et al., 2006). The 2006 FIFA World Cup in Germany marked a pivotal moment in the evolution of virtual advertising, enabling advertisers to deliver region-specific advertisements tailored to diverse global audiences. As a result, viewers in different parts of the world, such as America and Germany, were presented with different advertisements displayed on the stadium boards (Goldman, 2023). Similarly, the 2024 UEFA European Championship highlighted virtual advertising's success, with Coca-Cola tailoring region-specific ads to appeal seamlessly to local preferences in Europe and Asia (PTF Blog, 2024). From then until today, numerous prestigious sports organizations, leagues, and teams across various disciplines, including Football (e.g., UEFA, La Liga, Serie A), Hockey (NHL, IIHF), Rugby (World Rugby, NRL), Cricket (Cricket Australia, New Zealand Cricket), and others, have adopted virtual advertising. Virtual advertising has since expanded its possibilities, offering dynamic, region-specific content delivery, innovative solutions like virtual billboards, seat covers, and on-field graphics, and enabling advertisers to optimize revenue while enhancing viewer engagement and broadcast quality (Broadcast Virtual, Website).

This paper examines virtual advertising in Formula 1, a global sport with over 2 billion viewers across 180 countries (Formula 1, Website). It is chosen as a case study due to its use of virtual advertising and limited traditional branding opportunities on race tracks. Additionally, Formula 1 enables international brands to deliver tailored ads to specific regions and features its own streaming platform, F1 TV Pro, launched in 2018, making it ideal for this study. This study analyzes the impact of personalized virtual advertising on brand recall and investigates interactive, targeted signage for new advertising opportunities. Although prior research has investigated virtual advertising within the context of sports broadcasting, there remains a notable lack of focus on the effects of personalized signage on fan engagement and brand recall. Addressing this gap offers an opportunity to contribute novel insights into how brands can strengthen their relationships with audiences through the implementation of innovative advertising strategies. For instance, a Formula 1 TV Pro subscriber might receive a personalized birthday message, fostering a deeper emotional connection with the sport. Current literature poorly addresses how such personalization, like a custom message during a Grand Prix, influences viewer interaction and brand perception.

The article starts with an introduction to personalized virtual advertising technology and explores theories related to advertising effectiveness. The methodology section outlines an experimental

study that employs eye-tracking to compare audience engagement with personalized and non-personalized ads. The results analyze how advertisement format and placement affect viewer attention and brand recall. The conclusion contextualizes the findings within sports marketing, offering practical recommendations for advertisers and event organizers, while also reflecting on the study's limitations and suggesting ideas for future research.



(a) Non-Personalized Virtual Advertising Signage

(b) Personalized Virtual Advertising Signage

Photo 1: Depiction of the Research Problem: Comparison of Non-Personalized vs. Personalized Virtual Advertising Signage in Formula 1 Broadcasting

2. Literature Review

2.1 Overview of Virtual Advertising

Virtual Advertising is the integration of brands, logos, and animations through digital signal processing (Cianfrone et al., 2006; Pyun & Kim, 2004). The global virtual advertising market is projected to grow from \$12.9 billion in 2021 to \$31.1 billion by 2026, with a CAGR of 19.3% (Leadsom, 2023a). Its key advantages include: a) the ability to sell sponsorships multiple times and b) delivering customized messages for specific broadcast countries (Sander & Altobelli, 2011). This approach reduces costs by targeting specific markets and creating opportunities in previously unbranded spaces (Walsh, 2023). Key benefits of virtual advertising technology include enhanced commercial value for numerous prestigious sports disciplines, teams, and leagues (uniqFEED Blog, 2023; Porter, 2022; Sander & Altobelli, 2011; Cianfrone et al., 2006):

- Right holders can enhance the commercial viability of advertising space.
- Right holders can also create additional space despite restrictions from broadcast regulations or safety concerns.
- Brands can customize messages for local languages, increasing adaptability and interaction.
- Brands can target specific markets, minimizing expenses and inefficiencies.
- Sponsors can ensure compliance with local market regulations.
- Global brands can align messaging with regional campaigns.

Several research papers (Cianfrone et al., 2006; Nebenzahl & Hornik, 1985; Sander & Altobelli, 2011; Turner & Cusumano, 2000; Psyma, 1999; Pyun & Kim, 2004;) have examined the utilization of virtual advertising signage in the context of live sports event broadcasts. The study conducted by Sander and Altobelli (2011) stands out as valuable contribution, revealing that 77.5% of participants acknowledged the presence of virtual advertising signage. Furthermore, an immersive 92.7% correctly identified goal-side billboards, and 55.6% did not perceive this technology as irritating during television broadcasts. However, a 2002 study conducted by a German marketing firm revealed that while viewers generally accepted virtual ads, they expressed frustration when the ads appeared directly on the playing field, suggesting that they should not interfere with the main action on the

field (Sasse & Ludwig, 2002). Other research has demonstrated that virtual advertising can be effective, leading to much higher recall rates (Psyma, 1999). For instance, Pyun, Han, and Ha (2004) discovered that virtual ads remained on-screen significantly longer than traditional ads, leading to nearly double the recognition rates among spectators. Furthermore, the effectiveness of virtual advertising is influenced by the placement of the ads and the specific sport in which they used, as highlighted by studies emphasizing the importance of these factors in determining the overall impact of the advertisements (Park & Inou, 2018; Sander & Altobelli, 2011).

2.2 Advertising Effectiveness

It's essential to recognize that virtual advertising is a technology that represents a novel method of advertising. The objective of advertising in general is to inform, remind and persuade consumers to pay for the product/service (Percy and Elliot 2005), and the rely on them to gather information necessary for making informed decisions among competing brands (O'Guinn, Allen and Semenik, 2009; Strydom, Jooste and Cant, 2000). Over the past decade advertising has increased considerably due to its crucial role in the development and maintenance of brand equity (Belch & Belch, 2004; Shimp, 2010). Brand is the most valuable asset for companies, as it enables customers to identify and select particular products, fostering repeat purchases. The challenge for brands is to commit to consistently delivering a specific set of features, benefits, and services to the consumer (Kotler and Keller, 2009). The existing scholar conclude (Aaker 2010; Hauser 2011; Ye & Van Raaij 2004; Stapel 1998) the importance of building brand awareness, so to be recalled in consumers' minds (Aaker 2010; Brewer & Zhao 2010) and effecting on the consumption decision-making (Hoyer & Brown 2001; Macdonald & Sharp 2000; Aaker & Joachimsthaler 2000; Brewer & Zhao 2010). Moreover, a successful brand awareness involves not only the number of people who know about a brand (Hart & Murphy, 1998), but also how easily consumers can recall and recognize the brand, as well as identify the associated products and services (Keller, 2007; Macdonald & Sharp, 2003). Brand recall is defined as the ability of consumers to accurately retrieve the brand from memory when prompted with a relevant cue (Aaker, 2010). In contrast, brand recognition involves identifying a brand as one that has been encountered (Hoyer & Brown, 2001). It is the consumers' ability to confirm prior exposure to the brand when presented with it as a cue (Keller, 2007). Brand recognition also refers to the percentage of individuals who acknowledge having heard of a specific brand (Francois & MacLachlan, 1995) and requires that consumers accurately recognize the brand as something they have previously seen or heard (Aaker, 2010).

Advertising effectiveness is defined as the ability to imprint brand information in the consumers' memory (Wilson and Till, 2008). Nonetheless, it is critical to account for the sleeper effect, which proposes that an advertisement may not immediately impact consumer behavior after the exposure, but forces its influence over time (Cardwell, 1999). According to a study by Berger and Mitchell (1990), advertisements are more readily recalled when they are frequent exposed. Another key factor is that consumers should have prior awareness of the brand before exposure to the advertisement (Romaniuk, 2009; Ouwersloot and Duncan, 2008). Furthermore, research by Gerber and Terblanche-Smit (2014) demonstrated that a) extended exposure time of a brand within an advertisement enhances brand recognition (O'Guinn et al, 2009; Higgs, 2004) and b) early appearance of the brand in an advertisement increases its recognition (Zigmond et al., 2009; Higgs, 2004). They concluded that a brand achieves optimal recognition if it appears around two-thirds of the way through the advertisement (Gerber and Terblanche-Smit, 2014).

2.3 The impact of commercial billboards during a sports broadcasting

In this study, the focus is on embedded advertisements during sports broadcasting. Embedded advertising refers to the practice of integrating advertisements into media content such as TV shows, magazines, or sports events, where they compete for attention alongside other stimuli (Cain, 2011). A recent study by Nielsen highlights the effectiveness of this approach, showing that ads integrated into live content can boost viewer retention by 30% (PTF Blog, 2024). This method is increasingly favored by companies as it offers several strategic benefits. Unlike traditional advertisements, which often employ a direct and persuasive approach, embedded ads are seamlessly incorporated into the main content, making the promotional message less obvious and more natural (Cowley & Barron, 2008). This integration not only minimizes viewer resistance but also enhances the effectiveness of the advertisement. Moreover, embedded advertisements are easier to repeat within the content. Since the advertisement is part of the primary material, viewers can be exposed to it multiple times without experiencing the fatigue or boredom typically associated with repetitive advertising (Schmidt & Eisend, 2015). This repeated exposure is crucial, as it operates similarly to the repetition of standalone advertisements, where increased frequency enhances the likelihood of message retention by the viewer (Pitts & Slattery, 2004). The effectiveness of embedded advertising is also heightened when viewers' interest in the primary content fluctuates. During moments of reduced attention, embedded messages can capture the viewer's focus, ensuring continued engagement with the brand's message (Bennett, 1999). However, one drawback of embedded advertising is that multiple sponsors are visible at the same time, which can reduce the effectiveness of each individual message (Boronczyk et al., 2018). This issue is especially noticeable during sports events, where viewers, whether viewed live or through broadcast, are exposed to several sponsorship messages simultaneously. This differs from TV commercials, where viewers focus on a single brand (Ruth & Simonin, 2003).

The primary advertising tool in sports arenas is commercial billboards (CBSA), strategically positioned to enhance visibility for both in-person spectators and at-home viewers (Nebenzahl and Hornik, 1985). Bright colors and dynamic images improve visual impact (Al-Natour et al., 2013; HIVO - Blog) and foster emotional connections, enhancing consumer perception and trust. Repeated exposure boosts brand recognition and recall, while digital billboards with moving images create immersive experiences (Reber et al., 2004). Placement is critical, as billboards at court ends receive longer exposure than center ones, with Relo Metrics' 2024 report showing that Extra-Large and Multi-panel billboards offer more exposure time than other signage.

Billboard placement is crucial in sports advertising, and virtual advertising has enhanced this process. Directors can dynamically insert virtual signage, which is challenging in Formula 1 due to 5 to 7-kilometer tracks. Research in vision science underscores that the relative size of objects in the visual field directly impacts attention and information processing, as larger objects are perceived as more meaningful and engaging (Palmer, 2002). To optimize placement, marketers use "white space analysis" to identify unbranded areas for ad placement, boosting fan engagement and brand value. This involves computer vision, an AI technology that scans environments to find unused spaces and evaluate their expected media value for strategic decisions (Mike, 2020; Bullock, 2023).

Technological advancements like virtual advertising can enhance sponsorship efficiency through real-time adaptation of sponsor messages (Rumpf & Breuer, 2016). Understanding how sports content affects sponsor message processing is crucial, as watching sports generates audience arousal, especially when favoured teams compete (Kim et al., 2017; Biscaia et al., 2013). Research by Bruer et al. (2021) highlights the importance of game dynamics on viewer attention to sponsor brands, finding that attention declines when the game's outcome appears predictable and increases if a favoured

team is likely to lose. Additionally, attention to sponsor brands is higher in the first half of the game than in the second half.

2.4 Streaming Platforms, aka Over-The-Top Media Services

As presented in the Introduction of this paper, the current study focuses on the impact that personalized virtual advertising may have within streaming platforms, as it is the ideal medium due to the straightforward collection of subscribers' data and preferences. In the US, Nielsen reports that streaming platforms surpassed cable and broadcast television for the first time in 2022. Moreover, in major European markets, spending on sports rights through OTT services rose from 12% in 2021 to 20% in 2022.

Streaming platforms or Over-the-Top Media Services (OTT) refers to the direct delivery of video content to viewers over the Internet, bypassing traditional cable or broadcast television platforms (Vaidya et al., 2023). The rise of OTT services has greatly enhanced audience viewing experiences. Consumers are no longer bound by time or location, granting them the flexibility to watch more content across different devices, in diverse environments and in any device like laptop, desktop, mobile, tablet, Smart Tv (Hutchins and Sanderson, 2017). Additionally, OTT services can customize the viewing experience for each user, enabling the formation of personalized viewing patterns (Hutchins and Sanderson, 2017).

In addition, numerous studies have been published on user behavior on OTT platforms (Gonçalves et al., 2014; Kim, 2015; Kwak et al., 2021; Nagaraj et al., 2021, Xu et al., 2023). Nagaraj et al. (2021) found that the youngest generations, regardless of gender, are more willing to pay for OTT subscription prices. Moreover, research by Williams (2020) examines the factors influencing consumer engagement with OTT platforms in sports, highlighting how various motivations and preferences shape fan behavior. **"Acquisition of Knowledge"** through media consumption enables fans to gain insights about games, driven by their identification with teams and active engagement on OTT platforms (Trail & James, 2001; Chan-Olmsted & Xiao, 2019). This is closely linked to **"Advertising Preference"**, where targeting passionate fans with sponsored messages, especially during major events, becomes crucial for effective marketing, given the fans' deep connection to their teams (Seo & Green, 2008; Su, 2020). Furthermore, **"Content Expectations"** underscore the need for unique, personalized content to cater to on-the-go viewing habits, which is complemented by the **"Convenience"** factor, emphasizing the importance of quick access to information in fostering brand loyalty (Trail et al., 2003; Nee, 2013; Hwang & Lim, 2015). As consumers shift from traditional cable to more flexible OTT subscriptions, **"Cost"** emerges as a significant consideration, with adaptable pricing strategies providing a competitive edge (Williams, 2020). Additionally, the **"Entertainment"** value of OTT platforms lies in their ability to offer compelling storytelling experiences, although users may be less inclined to interact with other fans on these platforms (Karat et al., 2002; Seo & Green, 2008). The **"Escape"** factor, which refers to using sports as a means to overcome loneliness and provide mental break, further drives fan engagement (Korgaonkar & Wolin, 1999). **"Fanship"** is a key motivator for consuming sports content via mobile devices, reflecting the importance of strong identification with a team (Trail, Fink, & Anderson, 2003; Ha et al., 2017; Kang et al., 2015). Moreover, the emphasis on **"Information"** accessibility draws users to platforms that prioritize relevant content, as sports fans often focus on gathering information over other forms of content (Korgaonkar et al., 1999; Clavio & Walsh, 2014). Relatedly, **"Pass Time"** is another motivation for online sports viewing, while **"Sports Knowledge"** connects the information gained from traditional sports viewing to online consumption, further enhancing fans' understanding and engagement with the game

(Rubin, 1981; Dietz-Uhler et al., 2000). **“Team support”** also plays a vital role, with social support within fandom communities fostering cohesion through emotional, tangible, and informational exchanges (Shumaker & Brownell, 1984; Gill & Williams, 2008). Lastly, **“Technical Quality”** is essential, as high-quality streaming experiences on OTT platforms are crucial for maintaining consumer satisfaction and engagement as these services continue to grow (Karat et al., 2002).

2.5 Formula 1

In 2018, Formula 1 launched F1 TV, its official OTT platform, offering a comprehensive viewing experience for Grand Prix races, including live coverage, pre- and post-shows, press conferences, and documentaries (Formula 1, Website). The platform is accessible in 118 territories, with live streaming available in six languages across 85 regions (F1 Website, 2021).

F1 TV provides live and on-demand content to enhance fan engagement, a strategy initiated by Liberty Media’s acquisition in 2017 (Formula 1, Website). This approach improves accessibility while virtual advertising allows sponsors to customize messages for regional audiences, generating new revenue (Leadsom, 2023). Recognizing fan diversity in loyalty (Dwyer, 2011), engagement (Yoshida et al., 2014), and team identification (Wann & Branscombe, 1990; Wang et al., 2020) is essential.

With 500 million loyal fans, 24 races, and over 1.5 billion viewers, Formula 1 is one of the fastest-growing sports on social media (Formula 1, Website). For the 2024 season, there are 294 sponsorship agreements across 10 teams, averaging 30 partnerships each (Tafà, 2024). Thus, Formula 1 is a valuable case study for assessing the impact of virtual advertising technology due to its broad global reach.

2.6 Eye-Tracking

Eye-tracking technology monitors eye movement, revealing focus areas, gaze duration, and movement paths (Realeye.io, Website). It assesses viewer responses to advertisements by showing whether viewers focused on or glanced at specific text or objects (Isaacowitz et al., 2006; Orquin & Holmqvist, 2018; Wedel and Pieters, 2012; Duchowski, 2007). Yfantidou et al. (2018) state that eye-tracking enhances data collection and understanding of visual perception, allowing marketing managers to optimize consumer engagement with advertisements, product packaging, and in-store displays (Wang et al., 2022).

The area of sports marketing remains largely unexplored regarding consumer responses to sponsored advertisements using neurophysiological techniques like eye-tracking (Dos Santos et al., 2019). Traditional self-reporting methods often fail to accurately capture viewer attention and cognitive processing of online sports ads (Yoshida, 2017). Few studies have examined the impact of virtual advertising on spectators’ memory. For instance, Porter (2022) discovered that while virtual ads capture more visual attention than traditional in-stadium ads during NBA broadcasts, they tend to be less memorable. This suggests that despite their visual prominence, virtual ads engage viewers at a lower cognitive level, which leads to reduced memory retention.

Building on this gap in understanding consumer attention and memory, our analysis will explore the impact of virtual personalized messages on spectators compared to non-virtual personalized messages, using RealEye.io, an online eye-tracking platform. This research aims to establish an innovative approach to personalized advertising by exploring how brands can directly communicate

with individual consumers in the dynamic setting of live sports broadcasts, offering new insights into the evolving field of personalized advertising strategies.

3. Research Questions

The research addresses key questions regarding this technology: What is the average visibility of virtual advertising signage as a percentage of the total frame size during a Formula 1 Grand Prix broadcast (**RQ1**)? Does including personalized messages in virtual advertising reduce the time to first fixation on ads (**RQ2**)? Finally, how do the placement and format of virtual advertising, including non and personalized advertisements, influence brand recall and lasting impressions among viewers (**RQ3**)? By leveraging eye-tracking data, this study explores how personalized virtual ads can increase brand recall and recognition.

4. Methodology

This study employed two methodologies to address the research questions. For RQ1, a Python script was developed to measure the visibility of virtual signage in Formula 1 race frames using the formula: $\text{Visibility Percentage} = (\text{Signage Size} / \text{Image Size}) * 100$. This choice reflects the significant impact of visibility on Media Value Percentage and overall Media Value (Drive Sports Marketing Agency, 2023). Visibility, equating to exposure, is key for enhancing brand awareness and image (Cornwell & Maignan, 1998; Olson & Thjømøe, 2009). In sports sponsorship, "visibility" refers to the logo's percentage within the frame (Relo Metrics, 2022), as logo exposure during televised events can yield brand recognition and likability effects similar to a 30-second ad (Olson & Thjømøe, 2009). Understanding this helps stakeholders optimize exposure opportunities across different sports venues (VISUA, 2022).

We analysed all Formula 1 races from the 2023 season and selected frames featuring various virtual advertising applications. We verified the integration of these ads using onboard footage from F1 TV Pro. The final frames, standardized to 1440 x 900 pixels, were captured on a 16-inch laptop display to align with Over-the-Top (OTT) streaming capabilities. Ultimately, 22 frames were chosen from 10 different races in the 2023 season.

For RQ2 and RQ3, a preliminary experimental study was conducted using RealEye.io eye-tracking technology. The sample was chosen to reflect a demographic that aligns with active OTT sports viewers, particularly focusing on individuals aged 20 to 35, as this group is more likely to engage with streaming platforms and respond to personalized ads. The participants were divided into two groups of 10. Both groups were exposed to the same Formula 1 frames, but Survey B participants viewed three personalized virtual advertisements designed by the authors. Key metrics collected included Time to First Fixation, Time Spent, and Revisits to assess the effectiveness of personalized messaging and evaluate the influence of ad placement and format on brand recall. The experimental procedure commenced with webcam calibration, allowing the program to track participants' eye movements as they focused on specific areas of the screen. Realeye.io assigns a grade to assess the quality of eye-tracking data for each participant, evaluating aspects such as sampling rate, data completeness, and the percentage of time the participant's gaze was accurately recorded on the screen (Realeye.io, Website). This was followed by practical instructions outlining the experimental process. Participants then viewed 20 frames from the 2023 Formula 1 season, each featuring a virtual

advertisement displayed for 3 seconds, amounting to a total exposure time of 60 seconds. Afterwards, participants answered both unaided and aided brand recall questions about the ads. To minimize random guessing, the study incorporated dummy brands following Bennett's (1999) method. For added realism in brand recognition, three logos from actual Formula E sponsors—JULIUS BÄR, ABB, and PANASONIC—were included among 13 logos. These brands were selected due to their involvement in the motorsport industry, ensuring the authenticity of the sponsorship context while preventing bias in brand recall responses. This combination provided a realistic framework for analyzing the impact of personalized advertising in a controlled experimental setting.

Segmenting images into Areas of Interest (AOIs) is vital for assessing attention in eye-tracking studies, especially in complex environments like Formula 1 broadcasts with various stimuli, including racing cars and sponsor ads (Wang et al., 2022). This method helps identify elements that effectively capture viewer attention. The analysis aims to determine if personalized virtual advertising, such as signage featuring a viewer's name, increases attention compared to non-personalized ads.

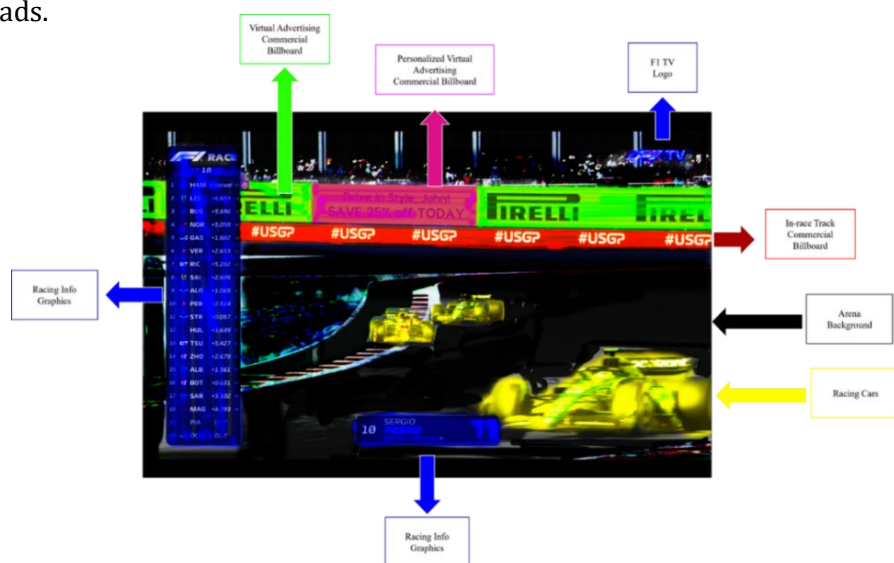


Photo 2: Key Areas of Interest Analyzed in Eye-Tracking Study - Source: Authors own work

5. Results

5.1 Research Question 1

Analyzing 22 screenshots from various 2023 Formula 1 races, each featuring at least one virtual advertisement, the average visibility of these signages was calculated to be 7.63% of the total frame size. In comparison, race standings -a common graphical element in Formula 1 broadcasts- covered an average of 10.81% of the frame. These findings underscore the prominence of virtual advertising within the visual field, indicating that strategic placement is essential to optimize visibility.

The data suggests that ad placement in particular track locations significantly enhances visibility. For instance, virtual signage positioned at key track turns, such as those in Mexican Grand Prix, achieved higher visibility rates. Additionally, ads integrated into track infrastructure, such as bridge banners in Abu Dhabi and the tunnel in Monaco GP, were notably effective in enhancing brand prominence. A prominent example is the Qatar Airways advertisement in Monaco's tunnel, which reached a visibility

rate of 20.31%, illustrating the importance of strategically positioned virtual ads to maximize brand exposure.

Frame Name	Detected Logo	Visibility Rate (%)
Formula 1 Lenovo Japanese Grand Prix 2023 - Turn 9	MSC CRUISES	4.95%
Formula 1 Lenovo Japanese Grand Prix 2023 - Turn 11	HEINEKEN	7.03%
Formula 1 Lenovo Japanese Grand Prix 2023 - Turn 5	ARAMCO	5.07%
Formula 1 Lenovo Japanese Grand Prix 2023 - Turn 8	DHL	0.86%
Formula 1 Heineken Silver Las Vegas Grand Prix 2023 - Turn 12	SALESFORCE	4.91%
Formula 1 Heineken Silver Las Vegas Grand Prix 2023 - Before Turn 14	SALESFORCE	6.13%
Formula 1 Rolex Grande Prêmio De São Paulo 2023 - Turn 15	MSC CRUISES	6.98%
Formula 1 Rolex Grande Prêmio De São Paulo 2023 - Turn 5	LIQUI MOLY	5.33%
Formula 1 Rolex Grande Prêmio De São Paulo 2023 - Turn 5 (A)	LIQUI MOLY	4.94%
Formula 1 Rolex Grande Prêmio De São Paulo 2023 - Turn 5 - Logo on the Track	LIQUI MOLY	1.42%
Formula 1 Etihad Airways Abu Dhabi Grand Prix 2023 - Before Turn 8	LENOVO	8.48%
Formula 1 STC Saudi Arabian Grand Prix 2023 - Turn 24	MSC CRUISES	2.61%
Formula 1 Pirelli Gran Premio D'italia 2023 - Turn 6	AWS	6.06%
Formula 1 Lenovo United States Grand Prix 2023 - Turn 12	PIRELLI	14.78%
Formula 1 Lenovo United States Grand Prix 2023 - Turn 7	QATAR AIRWAYS	3.39%
Formula 1 Lenovo United States Grand Prix 2023- Turn 19	PIRELLI	5.51%
Formula 1 Gran Premio De La Ciudad De México 2023 - Turn 5	LIQUI MOLY	23.64%
Formula 1 Gran Premio De La Ciudad De México 2023 - Turn 13	DHL	16.89%
Formula 1 Qatar Airways Qatar Grand Prix 2023 - Turn 9	MSC CRUISES	7.37%
Formula 1 Qatar Airways Qatar Grand Prix 2023 - Turn 5	ROLEX	10.67%
Formula 1 Grand Prix De Monaco 2023 - Turn 6	PIRELLI	0.50%
Formula 1 Grand Prix De Monaco 2023 - Tunnel	QATAR AIRWAYS	20.31%

Table I: Results of Virtual Advertising Visibility Percentage Analysis in 22 Frames from the Formula 1 2023 Season
- Source: Authors own work

5.2 Research Question 2

In the Preliminary experimental study, demographic data shows a balanced gender representation, with 50% male and 50% female participants. In Survey A, 20% were aged 18-22 and 80% were 23+, while Survey B had 30% in the younger group and 70% in the older group. The experiment aims to assess whether personalized virtual advertising messages enhance brand recall during sports broadcasts. The study divides frames into Areas of Interest (AOIs) to identify key zones viewers focus on during Formula 1, analyzing categories including Virtual Advertising Billboard, Non-Virtual Advertising Billboard, Racing Cars, Left Hand Side Standing, F1 TV Logo, Race Info Graphics, and Personalized Virtual Advertising Billboard (only in Survey B).

	SURVEY A		SURVEY B	
	%	n=10	%	n=10
Male	50	5	50	5
Female	50	5	50	5
18-22	20	2	30	3
23+	80	8	70	7

Table II: Preliminary Experimental Study Demographics - Source: Authors own work

The results from Surveys A and B highlight key insights into spectator engagement with commercial content during Formula 1 broadcasts, specifically regarding Personalized Virtual Advertising Billboards (PVABs). In Survey B, the introduction of PVABs resulted in increased viewer interaction,

achieving the shortest Average Time to First Fixation at 0.79 seconds, suggesting that personalized elements, such as viewers' names, can enhance audience engagement. The average Time Spent on PVABs was 0.69 seconds, comparable to the Time Spent on racing cars, which was 0.69 seconds in Survey A and 0.68 seconds in Survey B, indicating that personalized ads can attract attention similar to that of the main broadcast content.

Average Revisits, a measure of how often viewers returned their gaze to specific advertising areas, further highlights this engagement (Lewandowska, Realeye.io, Website – Glossary). In Survey A, Virtual Advertising Billboards had the highest revisits, reflecting sustained viewer interest, possibly due to their integration into dynamic the dynamic racing environment. In contrast, Non-Virtual Advertising Billboards had lower Revisits (0.25), and racing cars despite being the main point of the broadcast, had only 0.27 revisits. This pattern continued in Survey B, where Virtual Advertising Billboards scored a high Revisits (0.40), with personalized ads matching the high revisits score of 0.40.

SURVEY A							
Area of Interest	Average Time to First Fixation (s)	Average Time Spent (s)	Number of Fixations (SUM)	Ratio (%) - Average	Average Fixation Duration (s)	Average Revisits	Attention (Average)
Virtual Advertising Billboard	1,04	0,68	441	54,08	0,68	0,41	0,35
Non-Virtual Advertising Billboard	1,16	0,46	247	46,97	0,46	0,25	0,20
Racing Cars	0,96	0,69	328	53,67	0,69	0,27	0,34
Left Hand Side Standing Graph	1,09	0,63	223	52,50	0,62	0,17	0,10
F1 TV Logo	2,45	0,25	2	10,00	0,25	0,00	-2,08
Race Info Graphics	1,19	0,66	48	28,75	0,67	0,08	0,24
SURVEY B							
Virtual Advertising Billboard	1,04	0,65	446	60,25	0,65	0,40	0,19
Non-Virtual Advertising Billboard	1,11	0,56	312	48,03	0,56	0,32	0,31
Racing Cars	1,06	0,68	369	54,12	0,68	0,40	0,14
Left Hand Side Standing Graph	1,35	0,38	64	23,33	0,38	0,11	-0,13
F1 TV Logo	1,81	0,09	4	4,00	0,09	0,00	-0,61
Race Info Graphics	1,40	0,69	64	31,25	0,69	0,14	0,18
Personalized Virtual Advertising Billboard	0,79	0,69	31	46,67	0,69	0,40	0,20

Table III: Cumulative Eye-Tracking Results for Groups A and B in Preliminary Experimental Study - Source: Authors own work

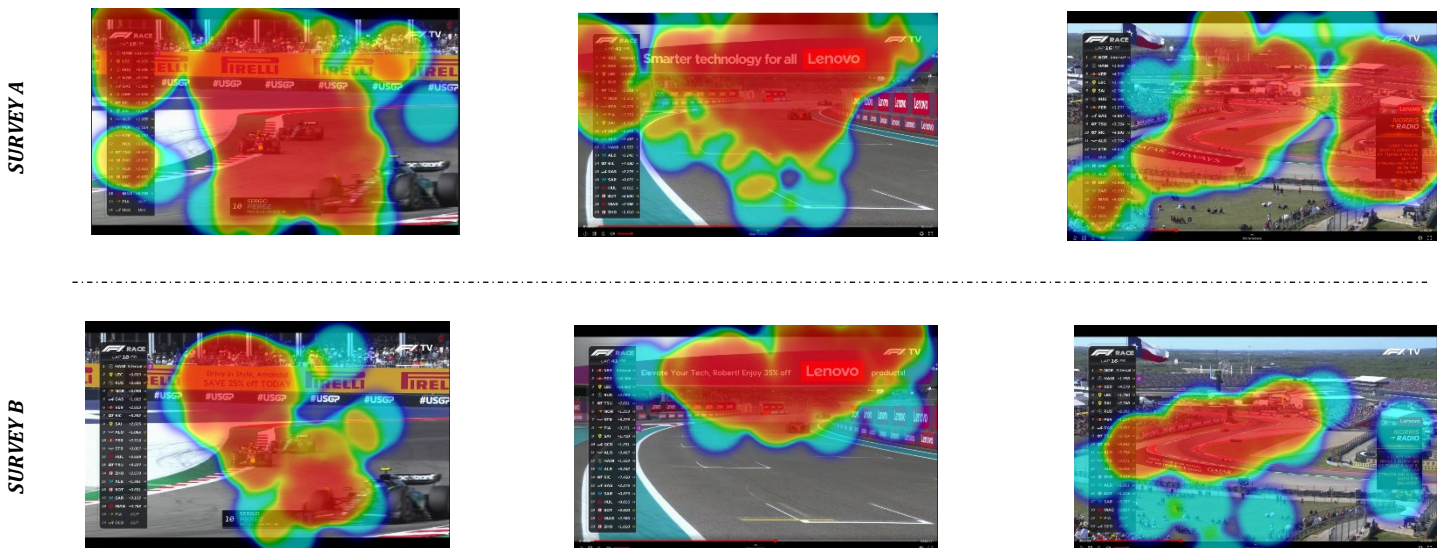


Photo 3: Comparative Eye-Tracking Heatmap Analysis: Survey A (Non-Personalized Virtual Ads) vs. Survey B (Personalized Virtual Ads)- Source: Authors own work

Analysis of above photos offers additional detail:

- **Photo 12 (Surv. A) & 3 (Surv. B) – Formula 1 Lenovo United States Grand Prix 2023- Turn 12 (Pirelli)**

In the frame featuring the Pirelli logo at Turn 12 of the Formula 1 Lenovo United States Grand Prix 2023, Survey A indicated that the virtual advertising billboard had an Average Time to First Fixation of 0.86 seconds and an Average Time Spent of 0.72 seconds, with 18 fixations. In contrast, the non-virtual billboard showed a longer Average Time to First Fixation of 1.40 seconds and a lower Average Time Spent of 0.31 seconds. In Survey B, the virtual billboard's Average Time to First Fixation improved to 0.47 seconds and Average Time Spent increased to 0.80 seconds, while the personalized virtual billboard had an Average Time to First Fixation of 0.52 seconds and Average Time Spent of 0.43 seconds, with 8 fixations.

- **Photo 13 (Surv. A & B) - Formula 1 Etihad Airways Abu Dhabi Grand Prix 2023- Before Turn 8 (Lenovo) -**

For this frame, including Lenovo at the Formula 1 Etihad Airways Abu Dhabi Grand Prix 2023, Survey A indicated that the virtual advertising billboard had an Average Time to First Fixation of 0.76 seconds, with a total of 27 fixations, signifying important viewer interaction. However, in Survey B, the Average Time to First Fixation increased to 1.35 seconds, but the number of Fixations rose to 32, indicating that while initial engagement took longer, viewers returned to the advertisement more frequently. The personalized virtual billboards achieved an Average Time to First Fixation of 1.14 seconds and an average Time Spent of 0.63 seconds with 17 Fixations, demonstrating improved viewer engagement compared to the standard virtual advertising billboard.

- **Photo 19 - Formula 1 Lenovo United States Grand Prix 2023- Turn 7 (Qatar Airways) -**

The analysis of Photo 19, featuring Qatar Airways during the Formula 1 Lenovo United States Grand Prix 2023, revealed that in Survey A, the virtual billboard had a quick Average Time to First Fixation of 0.84 seconds and an Average Time Spent of 0.62 seconds, with 16 fixations. In Survey B, the Average Time to First Fixation increased to 1.00 seconds and Average Time Spent rose to 0.90 seconds, although fixations decreased to 18, indicating less frequent engagement. The personalized virtual billboard had an Average Time to First Fixation of 0.72 seconds and an Average Time Spent of 1.01 seconds, with 6 fixations, suggesting that despite increased time spent, personalization did not effectively drive viewers to engage with the advertisement as often.

5.3 Research Question 3

The brand recall results from the surveys offer valuable insights into the effectiveness of advertising strategies deployed during Formula 1 broadcasts. Qatar Airways achieved the highest average unaided recall rate at 17.88% with stronger recall in Survey A (21.88%) than in Survey B (13.89%). Heineken and DHL also demonstrated strong and consistent unaided recall rates of 17.71% and 16.51%, respectively. Among the brands utilizing personalized virtual advertisements in Survey B—Lenovo, Pirelli, and Qatar Airways— the results varied. Lenovo's recall increased from 6.25% in Survey A to 8.33% in Survey B, averaging 7.29%, reflecting improved engagement with personalized elements. Similarly, Pirelli's unaided recall rose from 9.38% to 11.11%, averaging 10.24%. In contrast, Qatar Airways' unaided recall declined from 21.88% to 13.89%, indicating that while personalization can drive engagement, the effectiveness also depends heavily on the prominence of the ad message within the frame. Based on RQ1 results, the visibility percentage of Qatar Airways' virtual advertisement in the tunnel during the Monaco Grand Prix reached 20.31%, compared to DHL's 16.89% at Turn 13 of the Mexico Grand Prix and Pirelli's 14.78% at Turn 12 of the Austin Grand Prix, illustrating the strategic importance of high-exposure locations for driving brand recall.



Table IV: Comparative analysis of unaided brand recall performance - Source: Authors own work

Additionally, participants were asked to identify which brands left the most lasting impression. DHL and Qatar Airways were the top performers, each scoring 25%. Heineken and Lenovo also achieved moderate success, with 10% lasting impressions. On the other hand, brands such as Salesforce and Rolex performed below expectations, achieving impressions of 5% and 10%, respectively. Rolex, despite its historic and long-standing partnership with Formula 1, had limited visibility in the provided photos -appearing only once on a race graph- likely contributing to its lower scores. Major sponsors like Aramco and Pirelli, averaging 5%, also fell short in creating a strong impression. Brands like MSC Cruises, Liqui Moly, and Paramount+ failed to make any measurable impact, scoring 0% in lasting impressions across both surveys. Participants were also asked to recall the location of the brand that left the last impression, choosing from Track Infrastructure, Trackside, or Grandstands. The results demonstrated the critical importance of Track Infrastructure in driving recall and lasting impressions. For example, Qatar Airways, with 20.31% visibility, achieved 17.88% unaided recall and 25% lasting impression, emphasizing the effectiveness of strategically track locations as the tunnel in Monaco GP. Similarly, Heineken, associated with Track Infrastructure, demonstrated strong results with 95% aided recall and 17.71% unaided recall. Trackside placements are also proved effective, as evidenced by DHL (16.89% visibility, 85% aided recall, 16.15% unaided recall, 25% last impression) and Liqui Moly (23.64% visibility, 70% aided recall, 2.95% unaided recall). However, Liqui Moly's failure to generating lasting impressions (0%) despite high visibility.

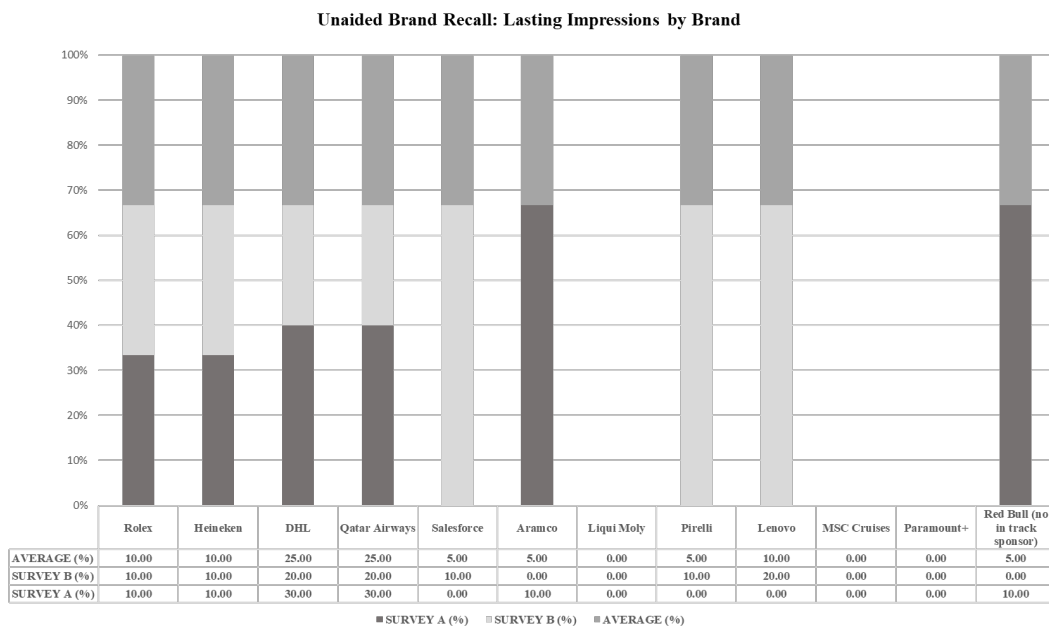


Table V: Unaided Brand Recall - Lasting Impressions by Brand - Source: Authors own work

Comprehensive Chart of Track Locations for Brands with Lasting Impressions

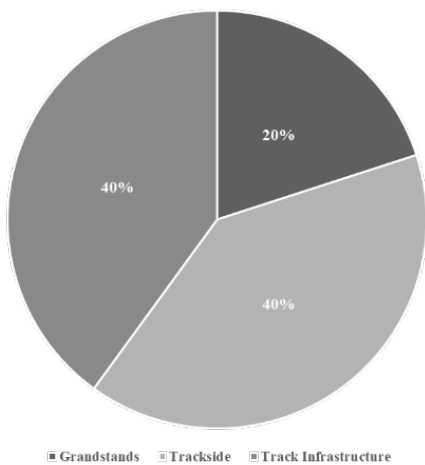


Table VI:
Comprehensive
Chart of Track
Locations for
Brands with
Lasting
Impressions-
Source: Authors
own work

Distribution of Lasting Impression Brands Across Track Locations

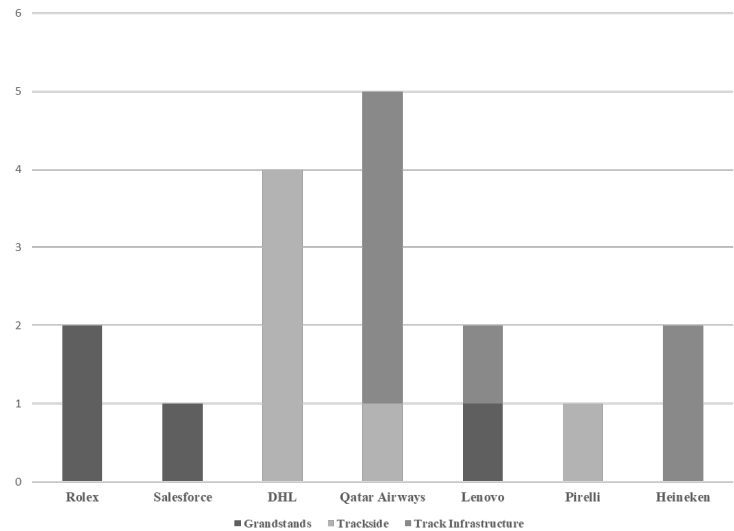


Table VII: Distribution of Lasting Impression Brands Across Track Locations- Source: Authors own work

In the final part of the survey, participants were shown logos to assess aided recall. The most aided recalled brands were Qatar Airways, Heineken, Pirelli and DHL, achieving 95% and 85% recognition rates, respectively. These results underline their strong visual branding and strategic presence. Lenovo (75%) and Liqui Moly (70%) also demonstrated improved recognition when prompted, indicating that while their visual identities resonate, unaided recall and last impressions could be strengthened. Mixed performers like MSC Cruises and Aramco recorded aided recall rates of 60%; however, a significant portion of participants failed to recognize these brands, highlighting weaknesses in branding execution among Greek Formula 1 fans. Dummy brands such as ABB, Julius Bär, and Panasonic, which lack any type of advertising in Formula 1, recorded minimal aided recall rates (0%-5%) validating the survey's control methodology.

Detailed Analysis of Aided Brand Recall Across All Brands

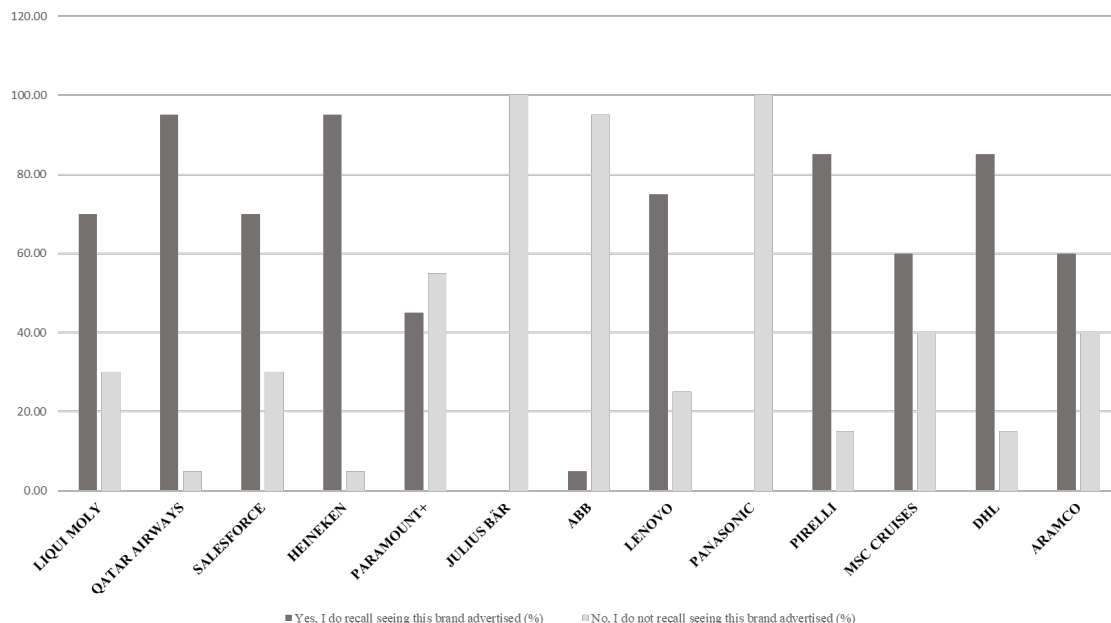


Table VIII: Detailed Analysis of Aided Brand Recall Across All Brands - Source: Authors own work

6. Conclusions

This study explored the impact of virtual advertising in Formula 1 broadcasts, emphasizing brand visibility, attention, metrics and the transformative potential of personalized advertisements to enhance audience engagement. In sports like Formula 1, in which the broadcasting cameras have to cover many miles of tracks, virtual advertising could be proved as a powerful tool for expanding brand exposure. Virtual advertisements occupied an average of 7.63% of the broadcast frame, with strategic placements driving visibility peaks in key areas such as the Monaco tunnel, where Qatar Airways achieved a 20.31% visibility rate.

The following correlation matrixes provided deeper insights into the relationship between eye-tracking metrics (Left Matrix) and brand recall metrics (Right Matrix). Key metrics, such as Fixation Duration, Revisit Rates, and Total Fixation Counts, exhibited strong positive correlations with overall attention and time sent on ads. Notably, a quicker Time to First Fixation negatively correlated with metrics like Fixation Duration and Revisits, emphasizing that ads capturing attention faster are more likely to sustain it. This is reinforced by eye-tracking data showing that personalized ads significantly reduced Time to First Fixation to 0.79 seconds compared to 1.35 seconds for non-personalized ads, demonstrating the effectiveness that personalization in sports broadcasting will have in immediately engaging viewers.

The study also revealed the complex dynamics of brand recall. While brands like Pirelli and Lenovo improved their recall rates between Survey A and Survey B – rising from 9.38% to 11.11% and 6.25% to 8.33%, respectively – Qatar Airways experienced a decline in recall from 21.88% to 13.89%. The authors included a personalized message in Survey B within the Qatar Airways frame, positioning it in a low-visibility size to evaluate its impact. This lower-visibility placement may have contributed to a decline in brand recall compared to other placements where the logo appeared. This highlights that visibility alone is insufficient for driving brand recall; factors such as ad size, placement, and creative execution play equally critical role. The correlation analysis further indicated that metrics like Fixation Duration and Revisit Rates are pivotal ensuring that ads leave a lasting impression on viewers, suggesting a focus on maximizing attention metrics to boost recall.

Overall, this study underlines that the success of virtual advertising in Formula 1 lies in a multidimensional approach that balances visibility, personalization, and sustained engagement. The correlation matrix revealed the strong interplay of attention metrics in driving advertising effectiveness, where faster fixation times and prolonged focus on them contribute to higher brand recall and recognition. Top-performing brands like Qatar Airways, Heineken, and Lenovo demonstrated the benefits of strategic placement and creative execution. Underperforming brands like MSC Cruises and Paramount+ could improve by addressing gaps in viewer engagement, as Ehrenberg (2000) argues that brand recall is stronger when the associative network model is leveraged effectively. By strengthening or creating meaningful nodes (brand concepts) and links (associations) within the consumer's memory network, these brands can reinforce connections and enhance recall.

From Photo 3, we also observe that in frames where the authors inserted a personalized virtual advertisement, the eye-tracking experiment provided compelling evidence. The result indicate that personalized virtual ads effectively captured participants' attention, with gazes concentrated more closely around the advertisements. In contrast, non-personalized frames showed a more dispersed gaze pattern, with participants' attention scattered across the frame.

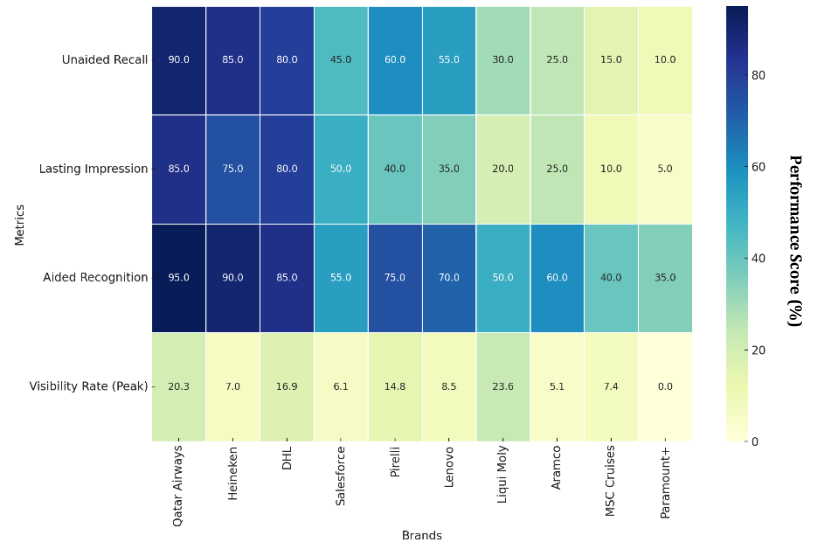
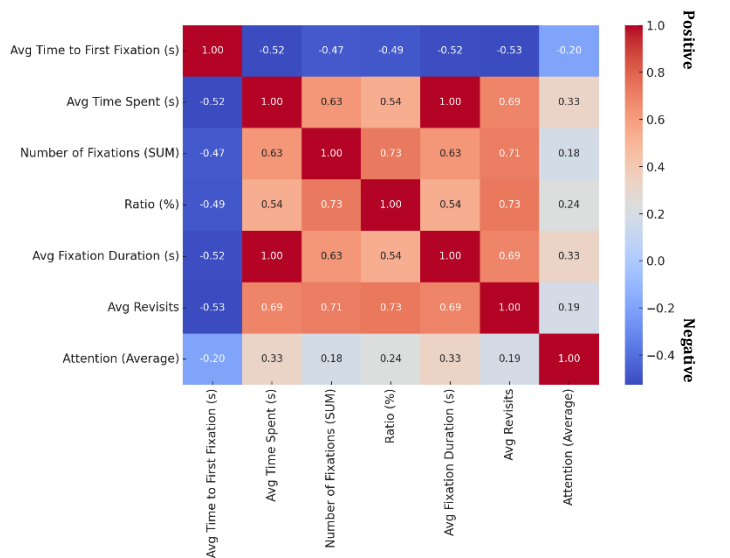


Table IX: Correlation Heatmaps of Eye-Tracking (Left Matrix) Metrics and Brand Visibility & Recall Metrics Across Brands - Source: Authors own work

6.1 Theoretical Implications

This study advances sports marketing research by revealing the effectiveness of personalized virtual advertising in enhancing brand recall and recognition, aligning with established work on targeted advertising, by showing how personalized content boosts brand recall and engagement (Percy & Elliot, 2005; Sander & Altobelli, 2011). Eye-tracking data supports previous findings (Duchowski, 2007; Wedel & Pieters, 2012), showing that personalized ads reduce fixation time and boost viewer engagement. This supports the idea that personalized content enhances emotional connection and ad effectiveness (Kotler & Keller, 2009; Ramsøy et al., 2019).

This study extends research on brand recall by demonstrating that personalized virtual ads not only capture immediate attention but also enhance memory retention. These findings align with overload theory, which highlights the importance of strategically managing visual elements to ensure effective information processing (Ha & McCann, 2008). By reducing clutter and focusing on targeted, personalized messaging, virtual ads optimize viewer engagement and recall. This suggests that future research could delve deeper into the impact of virtual advertising on long-term memory retention, exploring whether its effects persist beyond the immediate viewing experience (Berger & Mitchell, 1990; Maricic et al., 2019; Porter, 2022).

This strategic placement of virtual ads in high-visibility areas, such as Monaco tunnel, further underscores the importance of location for maximizing exposure, influenced by factors such as ad size and camera angles which have been shown to play a crucial role in ad visibility (Olson & Thjømmø, 2009; Rumpf & Breuer, 2016; Bullock, 2023). By utilizing eye-tracking, this study contributes a novel methodological approach, providing deeper insights into consumer attention and behavior (Yfantidou et al., 2018; Wang et al., 2022). Personalized ads' ability to quickly capture sports viewers' attention highlights their potential to significantly redefine sports marketing strategies.

6.2 Practical Implications

The findings of this study present a transformative opportunity for redefining sports sponsorships and fan engagement through the integration of personalized virtual advertising in Formula 1 broadcasts. This innovative advertising approach will not only address the limitations of traditional marketing strategies but also leverages the dynamic environment of Formula 1 to deliver tailored, contextually relevant content to global audiences. Personalized virtual advertising could offer stakeholders -including sponsors, advertisers and broadcasters- a powerful mechanism to optimize visibility, enhance brand recall, and create meaningful connections with viewers.

For advertisers and sponsors, the ability to tailor ads based on viewer demographics -such as language, cultural preferences, and age- ensures that messages are contextually relevant, thereby increasing brand recall and reducing ad waste. Personalized virtual ads offer a quicker Time to First Fixation, capturing viewer attention faster than traditional ads. This direct engagement, coupled with strategic placement on high-visibility areas of the track, is crucial for optimizing brand recall. Brands are encouraged to invest in virtual advertising in visually prominent spots, such as track infrastructures or track corners, where viewers are more likely to focus during the action.

For Formula 1 management, these findings provide valuable insights for monetizing virtual advertising in ways that go beyond traditional billboards. By strategically integrating personalized virtual ads into the F1 TV Pro platform, management can offer sponsors more customizable and interactive ad solutions that meet the evolving demands of digital viewers. This approach not only increases the commercial value of Formula 1's digital assets but also allows the organization to cater to a global audience with localized content, fostering deeper engagement across diverse viewer segments.

For sports marketers and broadcasters, the insights underline the growing relevance of personalized and interactive advertising formats in sports. Leveraging data from eye-tracking studies, marketers can better understand the effectiveness of ad placements and viewer interactions with personalized ads. This can guide future sponsorships strategies, enabling more efficient allocation of resources to maximize ad performance in live and on-demand broadcasts. Moreover, virtual ads offer a solution to consumers' growing resistance to traditional advertising by seamlessly blending promotional content into the live viewing experience, enhancing ad acceptance and reducing bothering.

Lastly, for viewers, personalized virtual advertisements create an opportunity for a more tailored viewing experience, where ads are relevant to their individual interests and viewing context. This approach contributes to a more engaging and enjoyable viewing environment, ultimately fostering stronger connections with both the sport and the brands involved. Enhanced viewer engagement with personalized ads also will benefit sponsors, as emotionally resonant experiences often lead to higher brand loyalty and customer retention.

7. Limitations & Future Research

While this study provides valuable insights into the impact of personalized virtual advertising in Formula 1 broadcasts, several limitations must be acknowledged. First, the study's reliance on static frame analysis and an online eye-tracking tool may not fully capture the dynamic and immersive nature of live broadcasts experience. Static frames, while useful for controlled experimental setups,

lack the continuous flow and contextual nuances of live sports events. As a result, the findings may not entirely reflect how viewers interact with personalized virtual ads in real-time environments. Additionally, the relatively small sample size of 20 participants in the preliminary experiment limits the generalizability of the results, though our ongoing larger experiment aims to address this issue by targeting 100 participants to validate our dataset. Another limitation relates to the scope of the study restricted to Formula 1, a fast-paced and visually complicated sport. The results may not generalize to other sports with different viewing patterns and audience characteristics. Moreover, the personalized messages used in this study did not include individual participants' names, potentially limiting the strength of the personal connection such messaging could evoke. Personalization at this level might create stronger viewer engagement and should be explored in future studies. Lastly, the study focused solely on static virtual advertisements, leaving other formats, such as video overlays, interactive ads, and personalization slogans, unexplored. These alternative formats could offer insights into how dynamic or interactive personalization influences attention, engagement, and brand recall.

To address these limitations, future research should incorporate real-time eye-tracking during live broadcasts. This approach would provide a more comprehensive understanding of how viewers engage with personalized virtual ads in a dynamic and complicated setting, offering a closer approximation to actual viewing experiences. Expanding the sample size and demographic diversity would also enhance the reliability and applicability of the findings, allowing for greater confidence in the conclusions drawn. Additionally, exploring how AI predictive models, which utilize historical sports viewing preferences, behavior patterns, and other factors, could enhance the appeal and engagement of virtual advertising is crucial. These models could be applied not only to live broadcasts or streaming but also to on-demand and social media content.

In addition, comparative research across different sports—such as soccer, basketball, and tennis—could explore how sport-specific factors influence the effectiveness of personalized virtual ads. Future studies should also examine the impact of integrating individual-level personalization, such as using participants' names or preferences, to assess whether deeper personalization increases engagement and emotional resonance. Furthermore, exploring a broader array of ad formats, including animated or interactive elements, could provide actionable insights into the design of virtual advertisements that optimize both viewer attention and brand recall. Addressing these fields would enrich the theoretical framework and practical applications of personalized virtual advertising, contributing significantly to the evolving landscape of sports media marketing.

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Appendix

- **Supplementary Data File:**
https://drive.google.com/file/d/1g39VKirplAj_MB2FVdEpOAM2ChLT4WxV/view?usp=sharing
- **Video of the Eye – Tracking Research Analysis:**
<https://drive.google.com/file/d/1MKWPkwltP2twc4iSY1D1Umu2yPDVbfn8/view?usp=sharing>