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ROADS, INTERIORS, GRAPHICS, AND RESEARCH TECHNOLOGY

Roads, Interiors, Graphics, and Research Technology

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INTRODUCTION

This issue of the *Interdisciplinary Journal of Signage and Wayfinding (IJSW)* provides a broad overview of the true interdisciplinary nature and breadth of the multiple and inter-related fields of inquiry involved in signage research. The articles in this issue also showcase the diverse research methods currently being used to explore some of the important questions related to efficiency, effectiveness, and aesthetics whose answers can serve to inform improved practice and policymaking related to signage and wayfinding specifically, and to visual communication more generally. What emerges from this seemingly eclectic collection of research is a surprising degree of overlap, pointing to the importance of a journal such as *IJSW* for informing specific areas of research related to signage and wayfinding, but also assisting researchers to access those findings emerging in allied fields.

In the first article, Hildebrandt and Auffrey's Road Signage and Contextual Communication on America's Legacy Highways reports on their long-term exploration of the visual communication along America's historic US highway system. Much of this five-year effort concerns on-premise signs. However, because of their intense focus on contextual influences, the research intentionally includes all the aspects of the built and natural environment that provides the visual setting in which signs compete for visual attention and seek to influence viewer behavior. Outdoor advertising and public informational and directional signage are also necessarily part of the archive of over 15,000 images. The authors are now extending their work to signage and wayfinding in the interiors of complex building environments as well. Their findings emphasize the critical importance of context; signs identically designed and placed may differ in how effectively they communicate their messages and ultimately influence viewer behavior, the result of differing environmental contexts. As such, the implications of their findings are significant for signage design, sign industry practice, and sign regulation.

Garvey and Klena's article, Parallel-Mounted On-premise Letter Height and Sign Size, provides a technical link to Hildebrandt and Auffrey's work, or perhaps Hildebrandt and Auffrey provide a broader contextual lens for the Garvey and Klena article. While Garvey and Klena do not directly address the impact of environmental context on visual communication, such context necessarily has important implications for related research in the future. The current article details a follow-up study to Garvey's 2006 research on driver detectability of parallel versus perpendicularly mounted commercial road signs that is widely used by the on-premise sign industry. In this current work, the authors offer revised minimum standards for parallel sign square footage and letter heights based on the smaller observation angles they measured, which differed significantly from those previously assumed; their recommended minimum letter heights are roughly doubled and sign sizes quadrupled. These results imply the need for fundamental re-thinking about the design, industry practice, and regulation of parallel signs to the extent that these are a primary means for visual communication. As the authors suggest, research is needed to further validate these results to accommodate a range of real-world environmental contexts.

The article by Peña, Ragan, and Harrison, Memorability of Enhanced Informational Graphics: the effects of design relevance and chart type on recall, adds important empirical evidence to our understanding of the impact of design enhancements in attracting visual attention to communicate a message to viewers, especially with respect to the use of charts. This research found enhancements considered to be "relevant to chart contents" assisted viewer recall of some elements, such as title and other thematic elements, but did not improve viewer memory of specific data values. Based on these results, the authors conclude that relevant enhancements can indeed improve recall of some chart content to the extent that enhancements are related. Further, and importantly, recall of information for charts with unrelated embellishments was worse than unembellished charts, suggesting poorly chosen enhancements may distract or interfere with recall and therefore should be avoided. These findings have important implications for the design and placement of signs (a la the contextual issues foregrounded by Hildebrandt and Auffrey) and raises questions for visual communication at several levels, suggesting the need for additional investigation. For example, how do these findings extend to the communication of less complex and technical information, such as those found in a typical on-premise sign?

Rahman and Mehta's article, Signage Form and Character: a window to neighborhood visual identity, compares the design and style (form and character) of signs in urban neighborhoods, noting how the signs of a neighborhood contribute to their visual identity or sense of place, "often representing the interplay of the collective social, political, cultural, and economic values of the people who live and work there." Their extensive visual survey of on-premise signs allows an exploration of signage typefaces, shapes, materials, and illumination as signifiers of place and documents how the collective signage in a neighborhood business district serves to create a defining identity or identities. Of particular interest for sign designers and regulators is their finding that signage for the non-place-based businesses associated with gentrified neighborhoods tend to be undifferentiated, generic, and visually monotonous. This raises a number of research questions for those interested in the process and consequences of neighborhood change.

Li and Huang's article, Visual Access Formed by Architecture and its Influence on Visitor's Spatial Exploration in a Museum, investigates how the physical structure of a museum influences the visitor's exploration of space. As such, there is a focus in this article, as in others, on the critical importance of visual context in visual communication for wayfinding. In this case, the museum interior architecture and design shapes a museum visitor's visual access (visual attention) and effectively determines which exhibits many (perhaps most) visitors (especially first time visitors) will experience. As such, the results hold that direct visual access is more important than physical distance in a visitor's choices about which areas of the museum to visit. While this finding affirms earlier wayfinding research, it also raises interesting research questions with respect to the specific challenges of visual communication and wayfinding in complex interior environments, linking it to the work of Tang, presented later in this issue.

Tang's article, Analysis of Signage using Eye-Tracking Technology, provides insight into the use and potential of emerging research tools for signage and wayfinding research. Historically, the design and placement of signs combined elements of art and craft and was based on a combination of acquired aesthetic sense and talent, and had a penchant for past practice based on learned experience and desirable outcomes. More recently, researchers have sought technology-based tools with more limited or at least defined biases. This search for objective measures of sign effectiveness has pushed researchers to explore vision science and human response to what can be displayed on a sign. For some, the use of 3M's Visual Attention Software was a breakthrough in this search for objectivity, as it provided validated predictions of pre-conscious viewing of static images. Recently, screen-based and wearable eye-tracking (ET) technologies have emerged as important tools for capturing objective data of visual attention. This article presents the results of an exploratory research design that assessed the use of multi-user ET technology and explored how sign placement and context affect the capture of visual attention. The research uses ET hardware and software in dynamic (video) real-world contexts to assess how visual attention is impacted by location and proximity to scientifically established features that draw human attention. The results show that these emerging ET technologies have substantial promise to measure the visual performance of signs in ways that earlier technology could not. These finding are important for signage and wayfinding research broadly, and ultimately can serve to inform advances in signage design and practice. The analysis of the highway and neighborhood signs, both perpendicular and parallel, could certainly benefit. Similar benefits could be achieved for assessing signage and wayfinding in complex interior environments.

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Sacramento 3,073 Miles: road signage and contextual communication on America's legacy highways

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Abstract /

Over a five-year period, photographic and experiential data was collected about signage design, placement and context along America's iconic legacy US highways. Over 10,000 miles were traveled and more than 15,000 photographs were taken to represent the broad range of signs, placements, and contexts representing current tastes, norms and trends, but also the nearly 100-year history of highway signage as an essential form of American visual communication. This work captures the use and evolution of road signage to communicate public safety, wayfinding, and commercial messages along historic highways routes, and establishes the special importance of the specific environmental context in which the signs are situated for determining how effectively they communicate their messages. Analyses of the signage using visual attention software tools show that identical signs with identical placement will capture visual attention differently depending on the specific characteristics of the visual context.

Keywords /

highway signs; visual communication; environmental context; visual attention.

Figure 1 / Where US 50 begins in Ocean City, Maryland

A recent exhibit at the Philip M. Meyers Gallery at the University of Cincinnati summarized five years of photography and analysis of highway signage and the built and natural environmental context along America's iconic roadways. The exhibit, curated by professors Hank Hildebrandt and Chris Auffrey, documents historic and contemporary signage found along three of America's iconic legacy US highways. Over a five-year period, professors Hildebrandt and Auffrey made 15 road trips to collect photographic and experiential data about signage design, placement and context. They drove 3,073 miles east-to-west across the middle of America on highway US 50 from Ocean City, Maryland to Sacramento, California; 1,407 miles south to north on highway US 61 from New Orleans to the Canadian border; 2,448 miles on historic Route US 66; and made additional trips to places such as Williston, North Dakota, Branson, Missouri and Huntsville, Alabama. In all, they logged over 10,000 miles and took more than 15,000 digital photographs. The exhibit depicts the use and evolution of road signage to communicate public safety, wayfinding, and commercial messages along historic highways routes, and establishes the special importance of signage design and placement for the specific environmental context in which the signs are situated for determining how effectively they communicate messages.

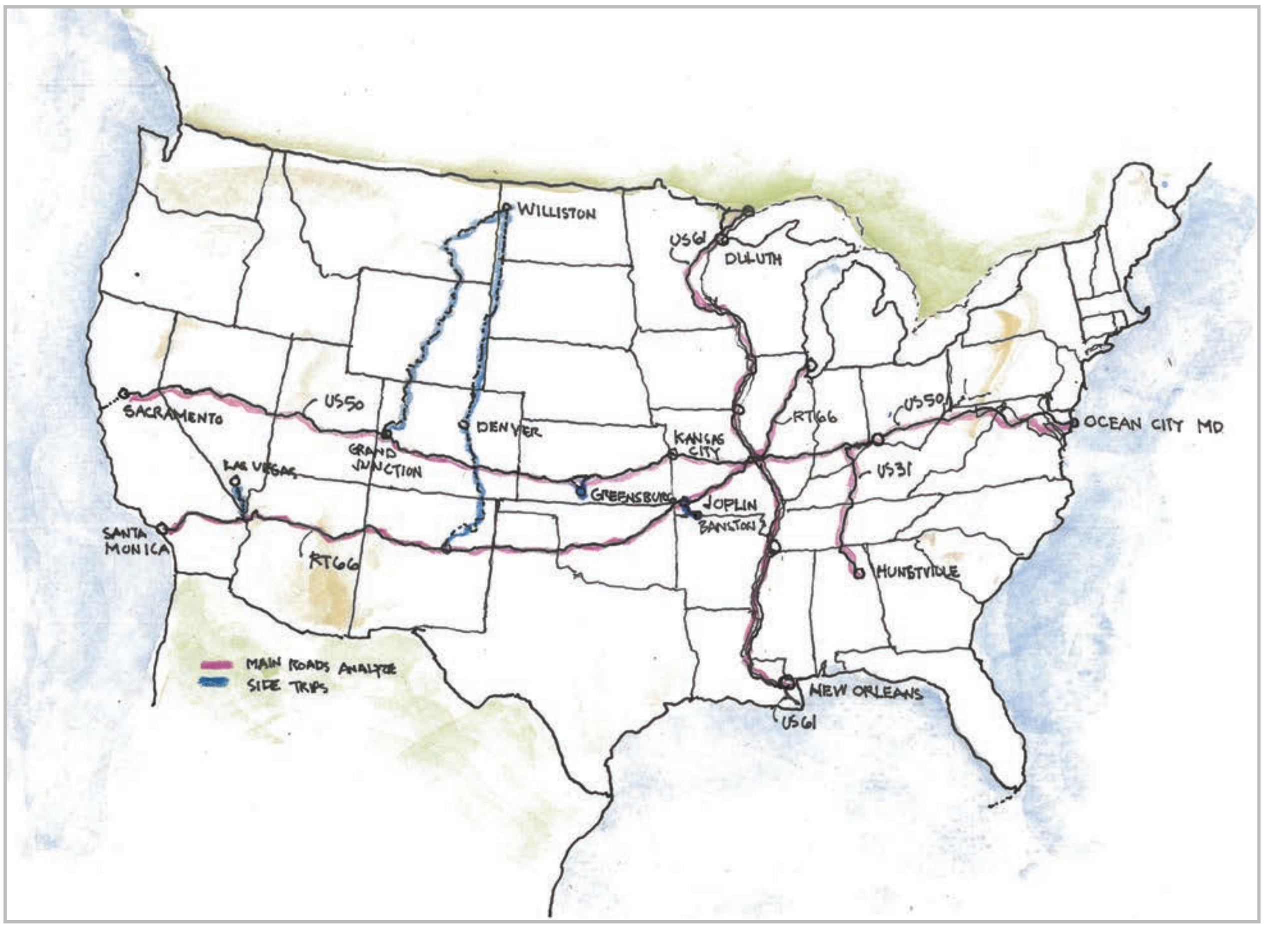

Figure 2 / Highways traveled over the five years of the project.

For this research project, highway US 50 was initially chosen because it is a central spine for the American continent that extends from coast to coast, is largely intact along its historic roadbed, and provides a broad range of contexts for signs and buildings. A typical day consisted of 12-16 hours of driving and taking photographs, often long into the night. The project started in Ocean City, Maryland and drove west along US 50: across the Appalachians, through the Midwest farm country and Great Plains, across the Rockies and western deserts, and over the Sierra Nevada to a final destination in San Francisco.

To better capture the broader range and depth of the American road experience, Auffrey and Hildebrandt expanded their travel to three other legacy US highways: US 61 from New Orleans to the Canadian border, US 66 from Chicago to Los Angeles, and portions of US 31 through Kentucky, Tennessee, and as far south as Huntsville, Alabama. Supplemental trips also were made to significant locations with unique signage contexts, including Branson, Missouri, Williston, North Dakota, and the Las Vegas strip. Ultimately, the goal was to observe and document, from the perspective of the motorist, those visual elements that signify road culture past and present, and that serve as foundations for the future. Visual attention software tools were used to analyze the images, allowing the capture of visual attention to be used as an indicator of the communication value of signs, symbols, and building form. The analyses focused on measuring the effectiveness of road signs as they are displayed and perceived in specific natural and built environment contexts. The results support an understanding of roads as corridors of complex environments

Figure 3 / Great American Steak & Chicken House, Branson, Missouri.

where movement and communication are intertwined in an infrastructure of vehicular movement patterns, organized around the efficient mobility of persons, in parallel with the infrastructures about communication of goods and services, wayfinding, and public safety. These diverse purposes can, at times, create competing priorities and lead to ambiguous (and sometimes amusing) conditions.

Signs were photographed from the front passenger seat of a car on public roads, as a typical motorist would see them while driving at normal speeds. These images include small local businesses, large commercial chains, public wayfinding, landmarks, and informational signs. From these, a range of broad typologies were created to assess the relative effectiveness of patterns of visual communication for individual signs and their context, as compared to other examples of the same type.

HIGHWAY US 50: SIGNAGE OF AMERICA'S LONELIEST HIGHWAY

Cities and towns in the United States have historically developed in settlement patterns linked by paths that became roads and highways. Whether connecting a crossroads hamlet of a few houses and a trading post, or larger intentional settlements and social assemblies, the continental expansion of the American landscape eventually required a formal system to facilitate the transfer of people, goods, and ideas. The emerging US highway system initially relied on Old World precedents, but quickly responded to the conditions of our nation's expansive landscapes and diverse geographic contexts. The demand for highways was

Figure 4 / El Rancho Hotel & Motel, Gallup, New Mexico

driven by rapid improvements in automotive technology and the affordability of car ownership, which facilitated the expansion of intercity transit. The result was a new American road culture and a distinctive American attitude about the "lure of the open road," where signage was critical for wayfinding and commerce.

As Americans took to the highway, concrete and asphalt ribbons between cities transformed rural landscapes to purpose-built road corridors serving the needs of commerce and freedom of movement. The legacy corridors of the original US highway system (started in 1926) provide an especially powerful display of American road signage, reflecting the evolving culture and systems of visual communication in the cities along these routes. It is in this vein that this research sought to document and analyze the road signage along America's iconic legacy highways.

The analysis focused on the effect of the surrounding natural and built environments on the visual attention captured by these signs. As such, it was considered that this knowledge can be used to better understand the design and regulation of visual communication in the future.

This case study of highway US 50 showcases the wide range and depth of signage across America and reflects the larger values of American transit and commercial attitudes. The mix of old and new signage describes the visual history of the highway system, and how different strategies for attracting visual attention and disseminating information evolved over time. Signs are reflections of culture and how society chooses to transmit information, in this case along the linear space of highways. The range of usage and intention in the signage also allowed for an examination of the distinct hierarchies of visual data. Through an understanding of the historical context behind the development of the highway system and a visual study of the system's signage, the research was informed by the strategies and evolutionary developments resulting in the signage seen today.

ROAD SIGN TYPOLOGIES: A SYSTEM OF CLASSIFICATION FOR ANALYSIS OF EFFECTIVENESS OF HIGHWAY SIGNAGE

Drivers today are exposed to many types of visual stimuli from the varied road signage along

Figure 5 / White Horse Trading, Williams, Arizona.

America's highways. The design and placement of road signage is focused on capturing the visual attention of those passing by to effectively communicate specific messages. It follows that signs are tightly linked to the built environment they are designed to describe, but they are also more than conveyors of messages; signs combine with the natural and built environment to make unfamiliar places and objects recognizable to unfamiliar audiences. The combination of sign, building, and other environmental contextual factors frame the sign's symbols and text within a broader physical setting, which impacts the way a message is viewed and interpreted.

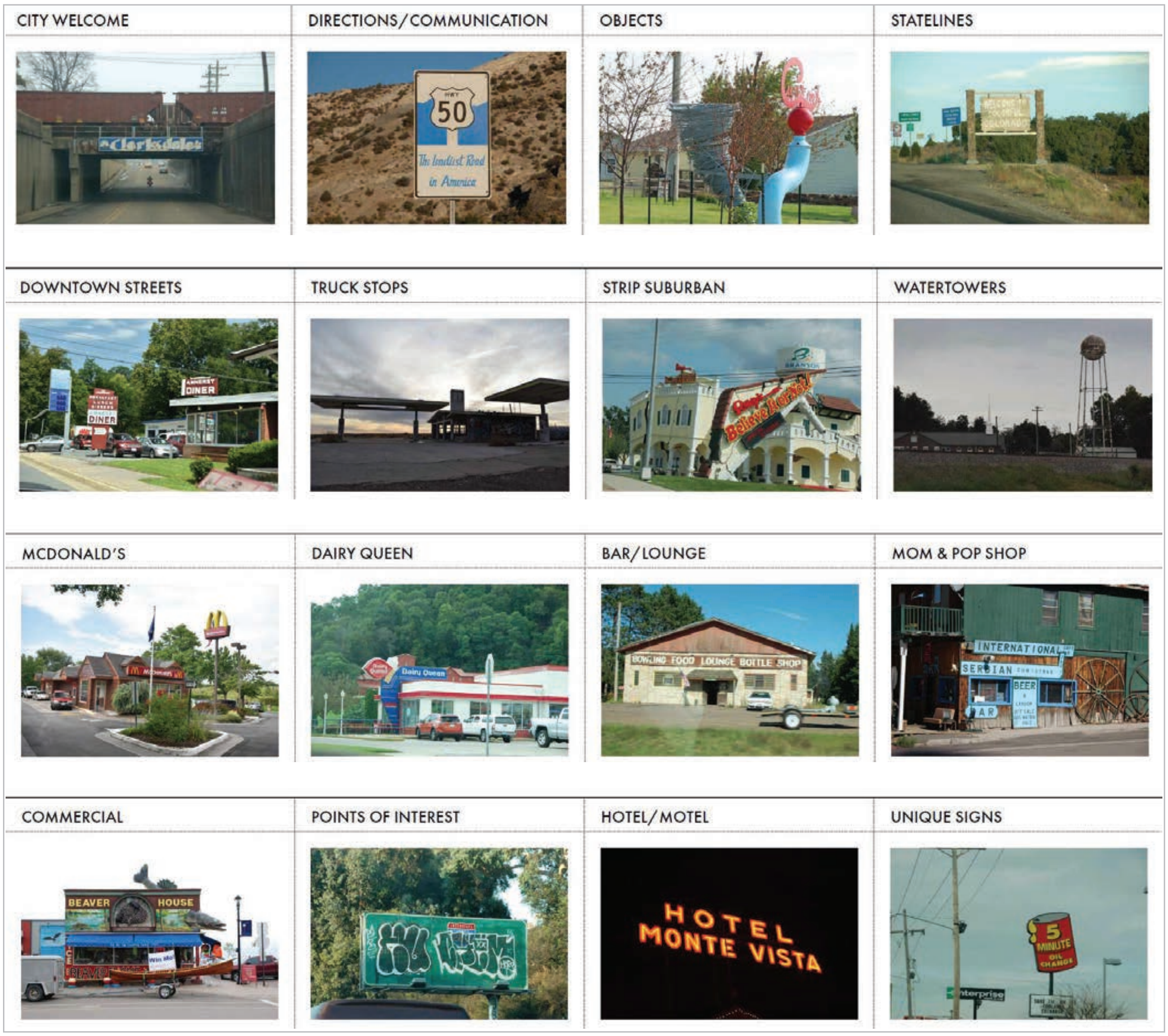

Figure 6 / Representative typologies of highway signage.

In order to estimate the effectiveness of a sign at communicating visual messages, we have set out to structure the objective criteria of communication in this format through categorization. Ultimately, a sign's ability to capture attention is dictated not only by its design and placement, but by its specific purpose and environmental context as well. To analyze this, we can apply existing research on the behavioral patterns that humans use to perceive visual objects.

From the images gathered over the course of this study, a matrix of sign typologies was developed. The intent was to classify the potential range of sign-environment combinations as they relate to program and context. Through this study we began to understand how complex the sign-context relationship has become over its evolution, and how that applies to current examples. These complexities are refined and expressed through these typologies, facilitating the process of arriving at meaningful conclusions through analysis. The resulting classification system has made possible deeper study of text and graphic messaging and has led to preliminary analysis of legibility and effectiveness of signage. By analyzing variants of signage from the same typology, our research is able to expose subtle variations of efficacy within these typologies.

Figure 7 / Results from analysis of roadway image using Visual Attention Software.

RELATED RESEARCH

A Study of the Probability that Motorists View On-Premise Signs Using Visual Attention Software

The study sought to investigate two topics: the extent to which on-premise signs (OPS) along US roadways attract the visual attention of passing motorists, and whether the OPS of national and regional businesses are more effective for this when compared to the OPS of locally-based businesses. Visual Attention Software was used to create data based on a sample of OPS and roadway contexts captured in photo images from along the 3,073 miles length of highway US 50. The findings suggest that a substantial proportion (approximately one-third) of the on-premise signs along roadways in the US are not being viewed by motorists as business intended. Also, findings show that the average probability of OPS of national and regional businesses being viewed is significantly higher than for the OPS of local businesses.

Figure 8 / Home "repurposed" road sign along US 50 near Kinsley, Kansas.

A Study of the use of Visual Attention Software (VAS) to Assess Wayfinding in Building Interiors

Students at the University of Cincinnati in the School of Architecture and Interior Design (SAID) applied VAS technology to a sequence of images representing a walking path through the DAAP building on the UC campus; the DAAP building is notoriously difficult to navigate. The research involved analysis of interior images from DAAP in their original form, and with enhanced, altered or new signage superimposed on the original images using Adobe Photoshop software. The results showed the altered and new signage consistently changed viewing probabilities for areas of interest and suggested that wayfinding in the building could be improved when guided by the results of applications of this type of analysis.

When taken together, the results of these two studies outline a clear direction for future research in this area: if simulations of signage alterations in DAAP show measurable improvements in a virtual analysis, it can be surmised that similar improvements can be made in signage for businesses and public wayfinding in many other exterior and interior applications. The results further suggest virtual analysis of the images could help to guide these improvements, and assist efforts to create research methodologies for large scale studies with human subjects and state-of-the-art eye tracking technology such as the Tobii Pro Glasses 2 (featured elsewhere in this exhibit).

ACKNOWLEDGEMENTS

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Parallel-mounted On-premise Letter Height and Sign Size

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Abstract /

Research and common sense attest to the fact that on-premise projecting signs are more detectable and are readable further away and at smaller sizes than wall-mounted signs. The objective of the current study was to conduct a small-scale field validation of earlier research on minimum letter heights for wall signs and to provide associated minimum square footage for these signs. Eight wall signs that varied in letter height and lateral offset were identified for evaluation on two roadways that varied in posted speed limit and cross-section in Nags Head, North Carolina. Using an empirical procedure involving driving and walking toward the signs, the legibility distances for these signs were evaluated and were found to compare favorably to past research that employed an analytical approach. An equation to determine sign size in square feet was also developed. Future research to further these findings is outlined.

Keywords /

on-premise signs; wall signs; commercial signs; visibility; legibility.

BACKGROUND AND OBJECTIVES

Research conducted by Zineddin et al. (2005) proved what sign manufactures and owners had previously merely assumed, that on-premise signs mounted perpendicular to oncoming motorists (e.g., projecting signs) are more detectable and readable from a greater distance and smaller size than their parallel-mounted (e.g., wall signs) counterparts. Garvey (2006) conducted a subsequent analysis to determine the difference between the two, namely the text size required for sign legibility and driver safety. The study resulted in a mathematical model and accompanying look-up table that could provide guidance on determining minimum parallel-mounted on-premise commercial sign letter heights.

While necessary and useful, that study did not include a field verification stage, so the recommendations and equations could result in some anomalies when applied to signs in the real-world. Also, while the study recommended specific minimum letter heights for parallel signs, it did not address an overall minimum sign size that could comfortably accommodate those letter heights.

The objective of the current study is two-fold, first to conduct a small-scale field validation to determine if the minimum letter heights predicted by Garvey (2006) provide sufficient legibility, or if some modifications are required. Second, sign size will be addressed by developing a look-up table or calculation that would provide minimum parallel sign square footage required for the recommended parallel sign letter heights.

PROCEDURE

Field Validation

Roadway Descriptions and Sign Locations

A set of eight parallel-mounted on-premise signs were identified in Nags Head, North Carolina (see Appendix A). The signs varied in letter height and lateral offset from the roadway. The roadways varied in posted speed limit and cross-section (e.g., number and width of lanes). The two roadways are:

1. North Carolina Highway 12 (NC 12 / South Virginia Dare Trail) is a two-way, two-lane primary highway with a posted speed limit of 35 mph. 10-foot wide travel lanes are separated by a solid double yellow no passing centerline. NC 12 has solid white edge lines and 3.5-foot wide shoulders (see Figure 1).

Figure 1 / North Carolina Highway 12, looking northbound

2. United States Route 158 (US 158 / South Croatan Highway) is a two-way, five-lane undivided arterial highway with a center turn lane. It has a posted speed limit of 45 mph, 11-foot travel lane widths, and similar to NC 12 has solid white edge lines and 3.5-foot wide shoulders (see Figure 2).

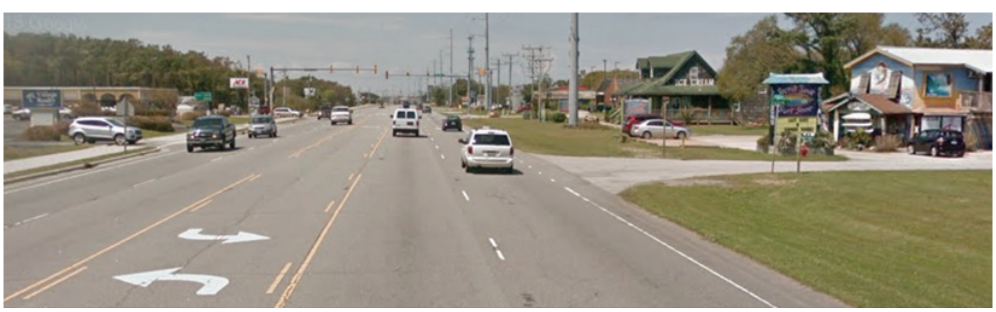

Figure 2 / United States Route 158, looking northbound

All four of the signs along NC 12 were viewed from the northbound lane with the signs on the driver's left, and therefore across one lane of traffic. Along US 158 two signs were viewed from the southbound travel lane and two from the northbound. As with NC 12, signs were on the driver's left, however, the viewing distance was greater given the number of lanes.

Data Collection

After permission was obtained from store managers, letter heights and offsets from the roadway edge lines were measured. The experimenters then determined the Maximum Available Legibility Distances (MALD) and the distances at which the eight signs could be read from a moving vehicle (hereafter called Sign Legibility). The results are tabulated in Appendix B.

Maximum Available Legibility Distance (MALD)

As described by Garvey (2006), the MALD is the distance between the driver and the parallel mounted sign where the observation angle first allows the sign to become readable. This angle is critical in Garvey's calculations; combined with sign lateral offset it determines letter height. Per Garvey, minimum letter height for parallel signs is based first and foremost on achieving an angle at which the signs are capable of being read. Based on an exhaustive literature review, that was set conservatively at 30-degrees, as smaller angles result in too much foreshortening. The distance on the road upstream of the parallel sign, where this 30-degree angle is met, depends on lane number and width and the sign's offset from the road edge. Theoretically, a driver could not read the sign beyond that distance, no matter how large the letters or the sign.

The letter height calculation for parallel mounted signs is determined by a Legibility Index (LI) of 1 inch per 10 feet. For example, if the MALD is 300 feet, letters would need to be 30 inches tall, at a minimum, in order to be legible at that distance. This ratio was identified as such because the shorter distances and larger viewing angle of parallel signs must be counteracted. This makes the sign much easier and faster to read. In comparison, the LI ratio for perpendicular signs is 1 inch of letter height per 30 feet of the MALD, three times the distance. If the offset angle is smaller than 30-degrees the sign can be read further upstream, meaning a longer MALD, therefore necessitating a greater minimum letter height. A larger offset, which means that the observer must be closer to the sign to read it, would allow for a smaller minimum letter height.

To precisely determine the MALD for each of the test signs, and to field test the 30-degree observation angle, the two experimenters walked along the edge of the two roadways during daylight hours and in fair weather and dry conditions. The experimenters consisted of one female age 46 and one male age 58, both with vision corrected to 20/20 with glasses, neither with any visual impairment other than the need for corrective lenses. When the sample signs, given their angle, became legible, the experimenters marked the location with an iPhone 6S' GPS / mapping function. The experimenters continued to walk until they became parallel with the sign, where they again marked the location. The distance between these locations was calculated via an application called Distance Tool. This gave the experimenters the measurements necessary to determine the MALD and observation angle. This same procedure was repeated for each of the eight target signs.

Legibility Distance

The two experimenters, one driver and one passenger, drove a 1997 BMW 328i along the two roadways at the posted speed limit in daylight and under fair weather and dry conditions. The passenger was tasked with reading the target signs as soon as they were able to do so with certainty. As with determining the MALD, that location was marked using an iPhone 6S, and when the vehicle was aligned with the sign, the passenger again marked the location. This distance was also calculated with the Distance Tool Application and again, the observation angle was determined.

Data Analysis and Results

The findings of these empirical tasks were compared to the predicted outcomes in Garvey (2006) to determine the efficacy of those results and establish real-world appropriate minimum letter heights for parallel mounted signs (see Appendix B). Results show that the average observation angle found by driving was 27.75-degrees, very close to the 30-degrees calculated by Garvey (2006). However, the average observation angle found while walking was only 16.14 degrees.

According to calculations in Garvey (2006), the minimum letter height, in inches, for a parallel mounted sign is 10% of the MALD; this is given because of the LI ratio of 1:10. Appendix B (column E) shows the theoretical minimum letter height calculation per Garvey (2006); columns L and V highlight the values for the 8 signs in this study, given walking and driving measurements.

Sign Size

The letter heights and the number of letters on the eight signs were applied to an equation to determine the appropriate associated sign area in square feet. Table 1 (see below) shows an example of this, with a sign that has 30, 18-inch letters. In this calculation, letter height is assumed to be equal to letter width, which is conservative and takes into consideration inter-character spacing. For most fonts, the width to height ratio is less than one, meaning that letters are taller than they are wide. The Garvey (2006) theoretical letter heights, and the walking and driving tasks from the current study are shown in Appendix B (columns F, M, and W respectively).

Table 1 / A summary of evaluation tasks used to assess recall in Session 2 of the experiment.

Sign Size Calculation:	
Height of characters (in inches)	18.00
Area for each character (in ft^2), assuming letter width = height	2.25
Number of characters = 30 (assuming 6 words with 5 characters each)	30.00
Total area of all characters (in ft^2)	67.50
Area of negative space (in ft^2), assuming industry standard of 60% of sign	101.25
Total sign size (in ft^2): text + neg. space	168.75

CONCLUSION

The 30-degree observation angle used in the parallel sign minimum letter height calculations found in Garvey (2006) is consistent with the mean of 28-degrees found in the driving legibility task conducted in this research. However, the observation angle of 16-degrees found when walking is roughly half. If this angle were substituted, the minimum recommended letter heights are roughly doubled and sign sizes quadrupled.

To determine whether or not the data warrant using these larger letter heights, a closer evaluation of the results was conducted. Two of the eight signs tested (Life is Good and Midgett's Seafood) used letter heights that exceeded Garvey's (2006) recommendations. Of those, Midgett's Seafood had appreciably increased legibility distances, increased MALD, and reduced observation angles. The Life is Good sign may have had similar results, but the letters were faded by the sun, thereby reducing both contrast and legibility.

This study, a follow up to Garvey (2006), found that smaller observation angles, and therefore larger letter heights and sign sizes, can improve the legibility distance of parallel mounted signs and bring their performance closer to that of perpendicular signs. Due to the nature of the experimental design, using real signs in the built environment vs. geometric calculations used in the earlier research, there were some uncontrollable variables, such as letter height, font, contrast, and offset. Future research is recommended to further validate these results using a larger subject sample size and greater experimental control over sign characteristics. This could be achieved by incorporating a closed track and specially designed signs into the experiment.

ACKNOWLEDGMENTS

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APPENDICES

Appendix A / Signs in varied letter heights and lateral offset from the roadway.

Appendix B: Data

	Number of Letters	Sign Offset	Letter Height		Sign Size	Maximum Available Legibility Distance (MALD)					Letter Height	Sign Size	Sign Legibility (Measured while driving at posted speed limit)									
	Measured	Measured	Measured	Garvey, (2006) Calculated Minimum	Garvey, (2006) Calculated Minimum	Garvey (2006) Calculated based on measured offset and assumed 30 degree observation angle.		Measured in walking study					Observer 1		Observer 2		Mean of 2 observers, 2 observations each					
N.C. 12		Feet	Inches	Inches	ft^2	Feet	Seconds	Feet	Seconds	Observation Angle (deg)	Minimum (inches)	Minimum (ft^2)	Feet		Feet		Feet	Seconds	MALD	Observation Angle (deg)	Minimum Letter Height (inches)	Minimum Sign Size (ft^2)
Red Drum Seafood	17	39.34	12	11.87	41.57	118.68	2.31	234	4.40	14.63	23.40	161.61	67	71	141	147	106.50	2.07	121.75	28.98	12.18	43.75
Farm Dog Surf School	21	39.42	9	11.88	51.49	118.84	2.32	245	4.66	13.86	24.50	218.84	82	82	170	139	118.25	2.30	132.15	26.52	13.22	63.67
Life is Good	10	44.50	14	12.90	28.89	129.00	2.51	242	4.54	15.36	24.20	101.67	115	136	142	116	127.25	2.48	142.66	26.88	14.27	35.33
Midgetts Seafood	15	31.50	23	10.30	27.63	103.00	2.01	266	5.08	11.16	26.60	184.26	155	147	160	171	158.25	3.08	166.42	18.03	16.64	72.12
U.S 158																						
Secret Spot Surf Shop	8	74.00	20	24.80	85.42	248.00	4.83	288	5.07	25.50	28.80	115.20	153	142	125	169	147.25	2.87	192.51	40.10	19.25	51.47
Outer Banks Boarding Company	20	93.50	28	28.70	286.00	287.00	5.59	505	9.43	16.51	50.50	885.50	339	374	341	352	351.50	6.85	379.66	22.21	37.97	500.49
Grits 'n Grill	10	108.00	24	31.60	173.36	316.00	6.16	549	10.25	11.60	54.90	523.27	262	220	319	298	274.75	5.35	316.94	29.90	31.69	174.39
Department of Motor Vehicles	3	148.50	30	39.70	82.09	397.00	7.73	528	9.53	20.50	52.80	145.20	325	312	376	397	352.50	6.87	404.55	29.39	40.46	85.24
Mean										**16.14**										**27.75125**		

Appendix B / Analysis determining the Maximum Available Legibility Distances (MALD) and the distances at which the eight signs could be read from a moving vehicle.

Memorability of Enhanced Informational Graphics: the effects of design relevance and chart type on recall

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Abstract /

Design enhancements are often added to charts, signage, and infographics to help garner attention or communicate a message. Despite concerns of design enhancements distracting from the underlying information, prior studies have contributed evidence that enhancements and even simple decorations can improve memory of visual displays. However, there is limited empirical knowledge about how the type of aesthetic enhancements influences memory, and what informational and data elements are remembered. We conducted an experiment testing chart types (line, pie, and bar), presence of color, and whether added enhancements were contextually related to the chart's data topic. The findings show relevant enhancements did improve recall of title and thematic elements, but enhancements did not significantly affect recall of specific data values. This suggests relevant enhancements can improve memorability of some chart content, but only if design styles are chosen well to match the information. Recall of chart topics for unrelated embellishments was worse than non-enhanced charts, which suggests that enhancements can distract or interfere with memorability if the viewer does not understand a meaningful connection between informational topic and design modifications.

Keywords /

visual design; information visualization; memory and recall; infographics; empirical study

INTRODUCTION

Infographics have proven to be highly effective means of communicating data in meaningful and understandable ways. Various forms of signage (e.g., posters, electronic messages, billboards) commonly take advantage of carefully crafted infographic designs to increase appeal and better inform or persuade viewers. Infographic signage include displays designed to educate the public about safety recommendations, civic issues, or useful information for travel planning. They are also used in marketing signage for appealing presentations of information related to products or services. Electronic signs can take further advantage of infographic displays that regularly update data to provide individualized or timely information to viewers.

While there has been interest in public use and interpretation of visualization with aesthetic enhancement and manipulations (Claes and Vande Moere, 2013; Holmes, 1984; Skog et al., 2003), visualization experts have long warned about the risks of "embellishment" or "chart junk" detracting from a visualization's ability to clearly communicate information (see Tufte, 1983). Despite the potential downsides to added stylistic enhancements, multiple studies have contributed evidence that visual enhancements can improve memory of visualizations (e.g., Bateman et al., 2010; Borkin et al., 2013; Quispel et al., 2016). One interpretation of such results is that prudent enhancements can make visuals more effective at communicating a message or making information more memorable.

Studies have found evidence that embellishment can influence the memorability of visual aspects of information presentations, but the extent to which embellishment can affect memorability of the information itself is less certain (Few, 2011). While several studies have investigated the relationship among the types of aesthetic embellishments and what elements of the visualization are remembered (Borgo et al., 2012; Borkin et al., 2013; Haroz et al., 2015), the design space is expansive, the result of the variance in types of fundamental data representations and embellishment strategies.

As such, limited empirical knowledge regarding what type of information is recalled from different visual properties of infographics exists and a clearer understanding of the implications of design enhancement for visualization memorability requires further study. In this paper, we present a controlled experiment to evaluate how added enhancements affect the memorability of a visualization's underlying data and informational elements. The user study follows a two-part design to evaluate recall of multiple types of chart information after one week. In addition to comparing the presence and absence of embellishments for multiple chart types, the study evaluates whether memorability is affected by the relevance of the enhancements to the data topic.

RELATED WORK

The widespread use of infographics and other visualizations in information environments has led to multiple lines of inquiry in the visualization community, including interview studies and quantitative experiments. These prior works include several quantitative studies on embellishments in charts, which inform several dimensions of our current study. Because the study presented here focuses on design effects for enhanced information displays, we prioritize background research in information visualization. A common goal for information visualization is to present data in such a way that it is readable, accurate, and understandable (Kosara, 2007). Graphical perception studies aligning with this goal have studied how different forms of fundamental visual encodings, such as mark position, length, size, and shading, influence how accurately people can interpret data values (Cleveland and McGill, 1984; Heer and Bostock, 2010; Saket et al., 2018; Szafir, 2017). Beyond graphical marks, graphical perception studies have also explored peoples' ability to extract statistical measures from visualizations (Beecham et al., 2017; Correll and Heer, 2017b; Harrison et al., 2014; Rensink and Baldridge, 2010; Wickham et al., 2010). Despite the growing trend of infographic-style visualizations in areas of daily life such as news and social media, comparatively few studies have targeted the use of infographics to inform, educate, or persuade casual observers (Kellaris and Machleit, 2016).

Design Enhancement, Infographics, and Memorability

Prior research has also focused on defining and measuring higher-level concepts in visualization; examples include creative data representations, visual enhancements, and their impact on users' performance and behavior (Bateman et al., 2010; Borkin et al., 2013; Bylinskii et al., 2017; Haroz et al., 2015; Lahrache et al., 2018; Ruchikachorn and Mueller, 2015; Zacks et al., 1998). We draw on the results and methodologies of several of these studies as the basis for the main questions explored in this paper, namely whether particular styles of design enhancements might influence a persons' ability to remember details of a chart. For example, Batemen et al. (2010) compared enhanced and plain charts by testing the possible influence of embellishments on their interpretation, accuracy, and long-term recall. In a study with two sessions, participants first looked at charts and answered a series of questions. They were then instructed to leave for a predetermined amount of time before returning and being asked similar questions about the charts they had studied; these questions focused on common facets of the chart, including its subject and data values, trends, and changes. After participants left, they were called back either five minutes or two to three weeks later for a recall session and when they returned, participants were again asked to describe trends and messages in the charts they had seen. The results of the study showed that while accuracy of data interpretation was similar between plain and enhanced charts, enhanced charts led to better long-term recall scores.

Other studies have found relationships between chart styles and memorability. In a study by Borkin et al. (2013), participants viewed a series of charts and were asked to specify when they saw repeated charts. The results highlighted how people were more likely to recall colorful visualizations, those using unique visual representations of data, and those using design enhancements that could possibly interfere with the accuracy of interpretation. In a later study, Borkin et al. (2016) revisited memorability by breaking down structural components of infographics further, with results suggesting that clear titles, supporting text, and redundancy help with the recall of visual representations of data they had seen previously.

Highly relevant to our research, Borgo et al. (2012) studied memorability of data charts with enhancements. They concluded that additional enhancements can increase memorability of chart information, but participants also took longer to interpret the charts prior to recall—meaning they had longer exposure. We observe that most prior related studies have focused on infographics gathered in the "wild," from existing visualizations in media and on the internet. In contrast, we adopt a study methodology with controlled variation of embellishments in charts to allow for a more systematic examination of the possible benefits and risks of using enhancements in charts. Haroz et al. (2015) is perhaps most applicable to the investigation of enhancement's relevance through controlled experimentation, as the research studied various approaches to incorporate icons and representative imagery into bar charts. Variations of embellishments included the use of a stretched icon behind bar charts, having the bars made of a row of small icons, or having a single large icon in place of each bar. This study considered the relevance of enhancements by including icons that either exactly matched an item name (e.g., a dog icon for a dog category) or was related to the category but did not match an item (e.g., a fish icon for a dog category). In this way, the mismatched icons would demonstrate a difference while still preserving relevance to a higher-level category (e.g., animals). The study found greater errors for recalling specific values with the presence of mismatched icons. In addition, their research found evidence that compared to simple charts without embellishment, participants gave more attention to bar charts with pictographic enhancements added.

The prior research on memorability of visualizations and infographics provides a strong foundation for continued research due to the number of observed effects of enhancements, but further evaluation is needed to develop a fuller understanding of the implications. Our research investigates goals similar to Borgo et al. (2012) and Haroz et al. (2015) with several key differences. First, our experiment includes relevance of enhancements as a controlled experimental factor. Haroz et al. considered relevance via icons that either (a) exactly matched bar chart categories or were (b) the wrong icons but were still related to the general topic of the chart. The study found the relevant-but-wrong visual embellishments were confusing and had negative effects on memorability, but the preservation of the relevance to the topic may have had a distraction or interference effect. Our study, therefore, aims to investigate entirely unrelated embellishments. Further, we study enhancements other than strict iconographic encodings with discrete values (e.g., five icons represent the value of five). In addition, our study provides a controlled comparison of fundamental chart types (bar, line, and pie charts). While Borgo et al. (2012) considered a broad variety of visual designs for breadth, chart design was not controlled as a factor in the study, whereas we seek to explicitly test for effects of different visual representations.

Our study also evaluates recall after a longer period of time (one week compared to seconds after chart viewing). Testing after an extended time has benefits for relevance in many realistic contexts (remembering data/charts days after reviewing them rather than immediately after), which may be the reason why some prior researchers have opted for longer term studies (see Bateman et al., 2010). Memory research has shown evidence of significant drops in recall ability over a period of days (Atkinson and Shiffrin, 1968). Moreover, our study design is influenced by memory research that has shown that relevance or meaningfulness of information influences how easily it can be recalled (Chase and Simon, 1973; Craik and Tulving, 1975; Smith and Graesser, 1981). This is especially important for our study of embellishment relevance.

Furthermore, we included data inspection tasks to encourage the acquisition of embedded information. Because the application of information is thought to reinforce memory, a longer duration is more important for a meaningful evaluation of differences (Nuthall, 2000; Ritchie and Karge, 1996). With the importance of systematic empirical research and separate independent experimentation, the presented research aims to further assess the topic of memorability while expanding the body of knowledge with increased attention to differences in chart types, differences in embellishment relevance, and prolonged time before recall assessment. Taken together, prior works at the intersection of visualization perception, design enhancement, and facets such as memorability and aesthetics yield a series of open challenges and methodologies and framings that inform our present study.

METHOD

We conducted a controlled experiment to evaluate how visual design enhancements and chart properties affect the memory of informational elements of infographics.

Research Goals and Hypotheses

Rather than focus solely on the memory of a visual message, our goal was to investigate whether memory of a chart's informational elements is influenced by chart design and aesthetic enhancements. In this study, chart information includes data values, chart titles, and overall topics or trends. By considering the effects of chart properties, we study whether viewers are internalizing the presented information or the imagery itself. Our research also evaluates effects due to the contextual nature of enhancement, focusing on visual additions that add supplemental imagery without manipulating the fundamental chart design. For this study, we use the term embellishment to emphasize that the design enhancements studied in this project are simple visual additions that do not modify the underlying data representation. In other words, the study focuses on the addition of "decorative" elements rather than cover the broader scope of design enhancements or alterations possible through graphic design.

We designed the experiment to assess whether the addition of embellishments helps improve memorability, or if it makes a difference if enhancements are contextually relevant to the chart's data and topic. Further, we were also interested in studying whether basic chart types and properties influence memorability of informational elements. More specifically, we wanted to test different fundamental chart types (e.g., line charts, bar charts, pie charts), because certain visualization formats may be better suited for certain data types and tasks and different shapes of data representations can influence interpretation (Jardine et al., 2019). The experiment accounts for possible interactions with color, since previous research has found evidence that chart color can affect memorability, and contribute semantic information for data categories (Borkin et al., 2013; Lin et al., 2013).

The following hypotheses were based on our goals and prior work:

H1: Contextually relevant enhancements will increase memorability of chart information compared to unrelated embellishments.

H2: Fundamental chart types (line, bar, pie) might influence memorability.

H3: Color images will be more memorable than black-and-white data graphics.

Experimental Design

The experiment followed a 3x3x2 mixed design where three chart types and three embellishment types were varied within subjects, and two levels of color were varied between subjects. For chart types, we tested line, pie, and bar charts in order to provide variety of different fundamental visualization designs for data representation. Figure 1 shows examples of the three chart types. Each row consists of three versions of the same chart modified according to the three different embellishment types.

The three types of embellishment (related, unrelated, and plain) controlled the style and decoration to the chart. Charts with related embellishments were designed to include supplemental visual elements that were thematically related to the topic of the chart. The left-most column of Figure 1 provides examples. In contrast, unrelated embellishments included stylistic modifications that were not related to the chart information (see middle column of Figure 1). Lastly, the plain embellishment type was designed to involve no (or minimal) visual markup. The right-most column of Figure 1 shows examples of the plain variations.

The final independent variable was presence of color, which had two levels: color or black-and-white; the black-and-white variations were simply grayscale images of the original color versions of the charts. All charts were designed to be readable in both variations. For line and bar charts, this was not an issue, however, pie charts often use different colors to denote different data categories, so the most straightforward design for the plain variations of pie charts would have caused problems. Preliminary testing with grayscale revealed difficulty in distinguishing and matching different shades of gray; therefore, patterned regions were used to identify categories in the plain version of the chart type (see right-hand column of Figure 1). Generic patterns (e.g., striped, textured, dotted) were chosen in an effort to maintain the minimal aesthetic style required for the plain embellishment level. To test recall the experiment was designed as a two-part study, with one week in between study sessions. In the first session, participants viewed and completed simple data interpretation tasks. One week later, a the second session assessed participant's memory of those same charts.

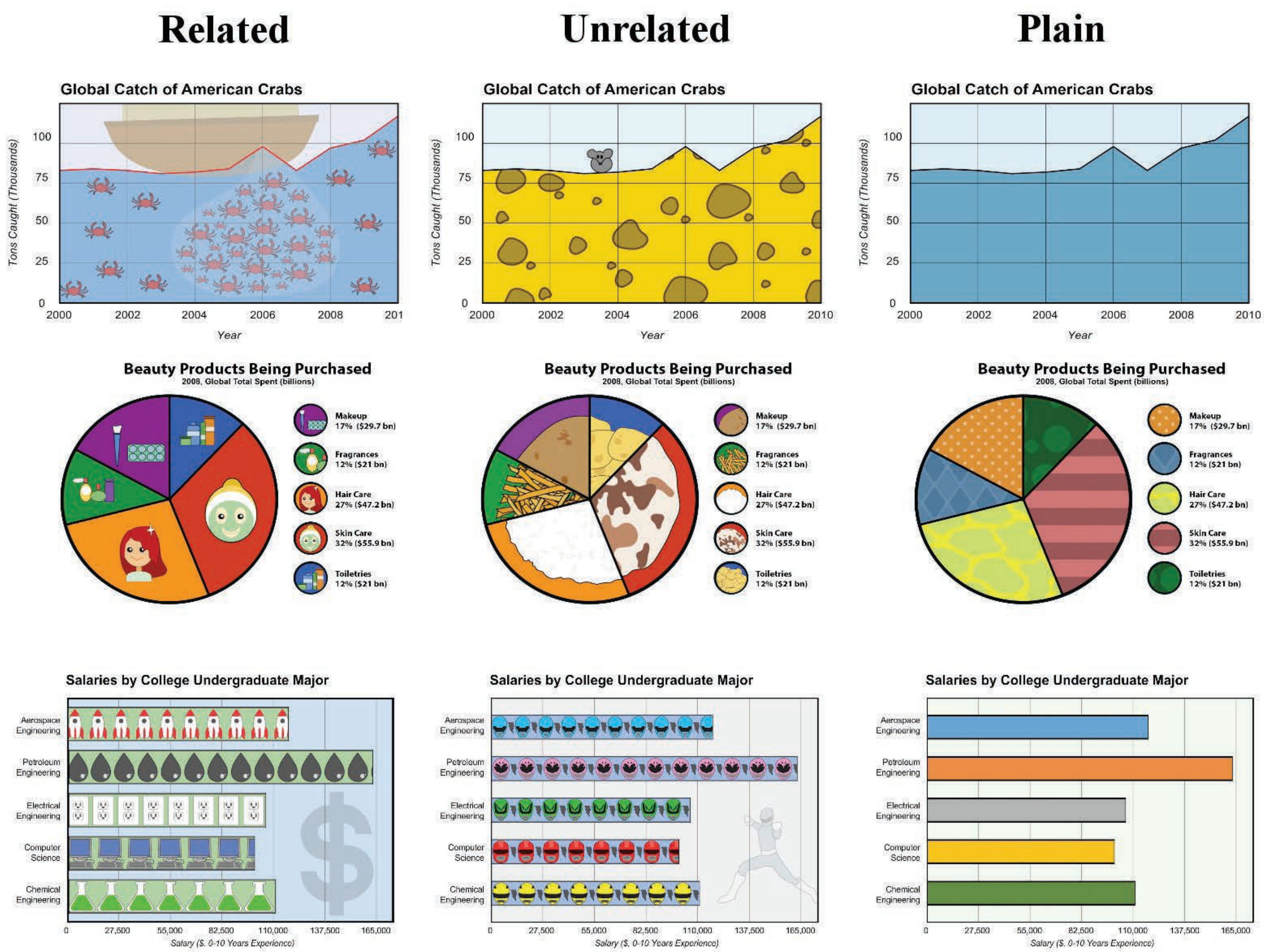

Figure 1 / Examples of charts used in the experiment. Each horizontal row consists of variations of the same chart modified according to the embellishment type factor. Each row also serves as an example of a different chart type for line, pie, and bar charts.

Dataset and Chart Development

In order to achieve experimental control for the different independent variables in the experiment we developed a dataset with a total of 180 charts. The charts were derived from 18 entries of base chart data divided evenly amongst the three chart types, each with five variations of embellishment types (two for unrelated, two for plain, and one for related). In total, we produced 90 charts (5 variants x 18 entries) to be used for each combination of the 3x3 within-subject factors. We then used the color charts to produce 90 more charts in greyscale, as color vs. black-and-white was controlled between subjects.

To support consistency, while also enabling creation of multiple unique combinations of charts, we developed design templates for the layout of bar, pie, and line chart types. Similarly, we developed template styles for the visual imagery of the embellishment types for each chart type. As seen in Figure 1, the template approach ensured that variations maintained an overall consistency in visual data encodings and chart design, and made it possible to change the embellishment imagery without modifying the underlying chart and data mappings. A single designer created all chart variations to maintain embellishment style across charts.

The data and themes for each chart were derived from the MASSVIS (Massachusetts (Massive) Visualization) dataset (Borkin et al., 2016) with numerous data visualizations scraped from online sources. Our criteria for choosing chart information was based on the complexity of the content, bias, understanding, and whether or not they could be represented visually. Occasionally, chart data was modified (e.g., title changes or minor value changes) to meet the purposes of the experiment. By creating our own visual imagery for the charts and a semi-automated system for developing the charts, we were able to maintain consistency in both style and layout.

The chart sets were generated to maintain similarity based on chart type. All pie charts had four or five categories, with all categories together totaling to 100%. Bar charts had five or six categories with varying ranges. Line charts had 9 – 24 data points based on how many were needed to show a trend, the ranges varied as well. When plotting values, we chose to make each chart with an axis range starting at zero in accordance with common visualization guidelines in order to reduce potential bias from deceptive visualizations (Pandey et al., 2015).

Tasks and Measures

The experiment consisted of two user-study sessions that included multiple question types. Participants were informed of both sessions ahead of time, but initial instructions were purposefully vague to avoid explicitly indicating the need to remember information across the sessions.

Session 1

In the first session, participants viewed 18 charts split by chart type and embellishment type. The initial ordering of the charts was randomized, as were whether the charts were in color or black and white. For each chart, two multiple choice questions were asked: identify and compare. The questions, refined in a pilot study, were designed to be readily understood, such that reviewing the chart would allow participants to determine a single correct answer from the multiple-choice options. The first question was always identification, which required participants to look up a certain value by interpreting the data graphic.

The following are examples of identification questions used in the study:

1. In 2008, which of the following beauty products was being purchased the most?
2. In 2011 what was the highest average number of hours spent in traffic in the U.S.?
3. Which location accounts for the least amount of robbery occurrences?

The second question was a comparison that required participants to interpret multiple data values and make a judgment about similarity or differences in magnitude. The following are examples of comparison questions from the study:

1. Which beauty product was purchased about as much as "Fragrances" in 2012?
2. In 2011, what month had a similar average

amount of hours spent in traffic to June?
3. Which location has the closest percentage of robbery occurrences to "Residences"?

When first viewing a complete chart with a title and label, the questions were not immediately visible. Participants were only shown the chart and asked to pay close attention to it. The questions were revealed either after five seconds or upon the participant clicking a button to signify they were ready. This brief delay was added to allow participants to familiarize themselves with the chart before they began reading questions and looking for solutions. The charts remained visible while they answered the multiple-choice questions, and a 'Confirm Answer' button was used to proceed to the next chart and set of questions. Exact time spent studying the visualizations varied by participant due to the flexibility of the online procedure, as the questions did not advance until all the correct answers were selected. This ensured that the users understood the chart contents. The system did not provide the correct answer when incorrect answers were given, and the rate of correct response was not included in analysis.

Session 2

The second session included four separate tasks: title recall, value recall, visual recall, and theme recall. As much as possible, these tasks and their order were designed so earlier tasks would not bias or assist recall for the following tasks. Table 1 provides an abbreviated summary and order of task types from session two. The title recall task was designed to assess how well participants could recall the titles of the charts viewed in the first session. It was administered as a recognition task, where no charts were visible, and participants were asked to select the titles of charts they recalled from the previous session. Titles were presented in a checkbox list of 30 randomly ordered titles distributed over three pages, 12 of which were fabricated. To promote the idea that some might be false, the participants were not required to select a title before proceeding to the next page.

For the value recall task, the goal was to test participants on their recall of the correct answers of the same identification and comparison multiple-choice questions that they answered in the first session. The ordering of the answer choices was the same as before, but charts were not available to assist in answering the questions.

The third task was visual recall, designed as an alternative measure of how well participants remembered the chart data values. Rather than requiring a numerical answer, the visual recall task was assessed based on the appearance, shape, or trend of the chart. Since session one included an identification question pertaining to a value on the chart, we tested visual memory of the charts themselves. For every chart presented in session one, participants were given an interactive version. To avoid interference with the following task, they did not include titles, labels, or axes. In addition, the data value from the identification question was modified from the original, in that the value was shown at half the chart's maximum value range. Participants were asked to adjust the value to match what was seen in session one (see Figure 2). The chart included an arrow that pointed to the adjustable data value—that is, a category for bar or pie charts, or a point for the line charts.

Participants used a pair of up-and-down arrow buttons to interactively increase or decrease the indicated value within a range; all values could be increased to the maximum of the value range and decreased to the minimum of the value range. The method for changing the data value and altering the visualization

Table 1 / A summary of evaluation tasks used to assess recall in Session 2 of the experiment.

Recall Task	Description
Title	From a list, select titles from session 1.
Value	Answer identify and compare questions from session 1 without chart.
Visual	Match the shape of provided chart to session 1 by interactively manipulating a value.
Theme	Given an unlabeled chart, select the theme best matching the charts from session 1.

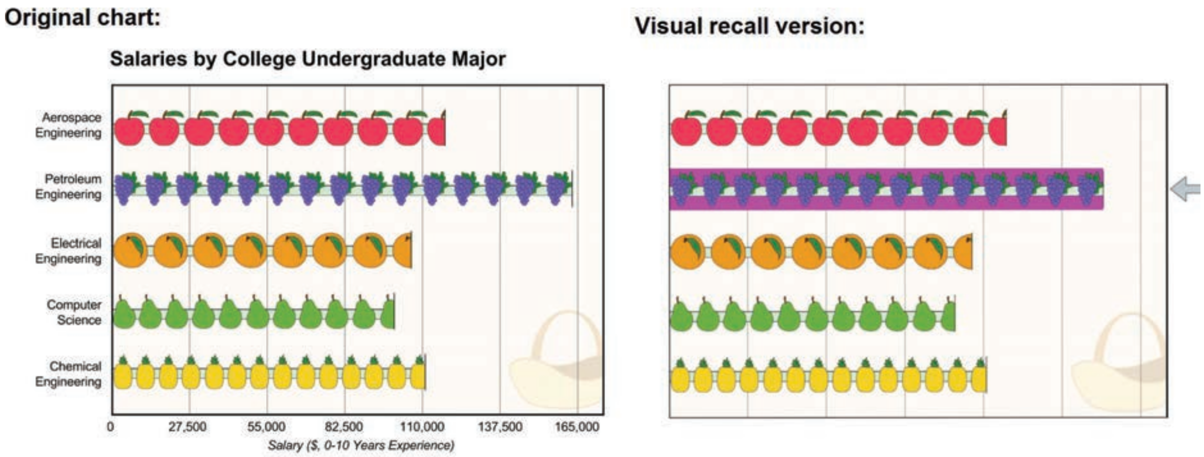

Figure 2 / In the visual recall task, participants interactively manipulated a value on the chart. The left image shows the original version of the chart seen in the first session, while the right shows the version used for the visual recall task of the second session. The arrow on the right side of the chart and the pink-highlighted background indicate the adjustable value. The interaction versions did not include textual labels.

varied based on appropriateness for the chart type. For instance, adjusting the value represented by a bar would increase/decrease the bar length without effecting other categories. However, adjusting any single value in pie or line charts affected the perception of neighboring values. To compensate, we also adjusted neighboring values to make any change compatible with the chart composition. When adjusting the value of a point in a line chart, the nearby points along the line were also adjusted using an exponential function to determine the weight of influence. Doing this allowed more realistic adjustments to the specified value without causing drastic spikes or dips in the chart and a similar approach was used for pie charts. To always keep the total of pie chart categories at 100%, changing one value required all other values to be inversely adjusted in an equal split.

Theme recall, the last task of session two, was used to evaluate how well participants could recall the theme of the chart if shown the chart without textual information. Participants were shown the unlabeled chart and asked to select the main theme from six choices. For example, if the chart was a pie chart of favorite Girl Scout cookies, the correct theme would be favorite cookies. The composition of incorrect options depended on the embellishment type of the given chart. If it was a related embellishment, the correct answer was in one of the three options related to the imagery, and the other three options concerned alternative topics. If embellished without context, three incorrect options were related to the imagery, two were fabricated as alternatives. For the plain conditions with no imagery, having multiple related answers could have been interpreted as hint about the nature of the correct answer; therefore, to avoid biasing participant answering, all five incorrect options were fabricated choices for the plain conditions.

Procedure

The study was conducted as an online study, with participants recruited through university email distribution and a ten-dollar (USD) participation incentive. Participants were not informed that they would be asked questions involving memory and recall; they only knew they would be answering questions about charts. Volunteers were sent a unique link to the web application. At the beginning of the first session, they were asked to digitally consent and fill out a background questionnaire. They were then shown instructions and an example of the types of multiple-choice questions they would be answering. The first session asked two questions for each of the 18 charts (a total of 36 questions) and had an average completion time of approximately 13 minutes.

Seven days later, participants were emailed with instructions for completing the second half of the study. To ensure similar amounts of time between sessions for participants, we required the second session to be completed within two days of the one-week notice, meaning that all successful participants completed the study within seven to nine days. Before each of the four tasks for this session (see Table 1), instructions with example images and questions were shown to clarify the task. The ordering of tasks was held consistent for all participants, though the ordering of charts was randomized for each participant. Completion of the second session took approximately 15 minutes.

Participants

The experiment had a total of 90 participants, but only 80 completed both sessions and did not identify as colorblind. Only participants who completed both sessions were included in the analysis. Of these, 32 identified as male, 47 identified as female, and 1 did not specify gender. Based on self-reports of education attainment, the majority of participants either completed high school (27) or held a Bachelor's (23) or Master's (23) degree. Several participants reported having PhD (4) or indicated "Other" (3). Ages ranged from 18 to 58, with a median age of 24.

RESULTS

We tested the effects of independent variables of embellishment type, chart type, and color on title, value, visual, and theme recall tasks from session two. Quantitative results from the tasks were shaped into a score by first assessing correctness per item for each specific task, then the scores were averaged for each task per participant. We analyzed the scores using 3x3x2 repeated-measure Analysis of Variance (ANOVA). If a significant main effect occurred, a Tukey test was performed for post-hoc analysis. We only discuss the significant effects in this report.

For title recall, where participants were asked to recall titles of charts shown in session one, the scores for the task were a count of the number of correctly selected titles. Figure 3 plots mean scores with standard error. There was a significant main effect in chart type, $F(2, 16) = 4.61$ and $p = 0.011$, and embellishment type, $F(2, 16) = 4.05$ and $p = 0.019$. Bar charts performed significantly better than line charts ($p < 0.01$). Related charts scored higher than unrelated charts ($p < 0.05$) and almost significantly better than plain charts ($p = 0.058$). Since this task was more concentrated on the message of the chart, it makes sense that related charts tended to score higher.

For value recall, where participants were asked to answer the same identify and compare questions from session one, the score was the average number of correct answers. There was a significant main effect in chart type with $F(2, 156) = 4.39$ and $p = 0.014$. Bar charts performed significantly better than line charts $p < 0.01$ (see Figure 4). It is worth noting that this same effect was significant for title recall. There were no effects of embellishments on recall.

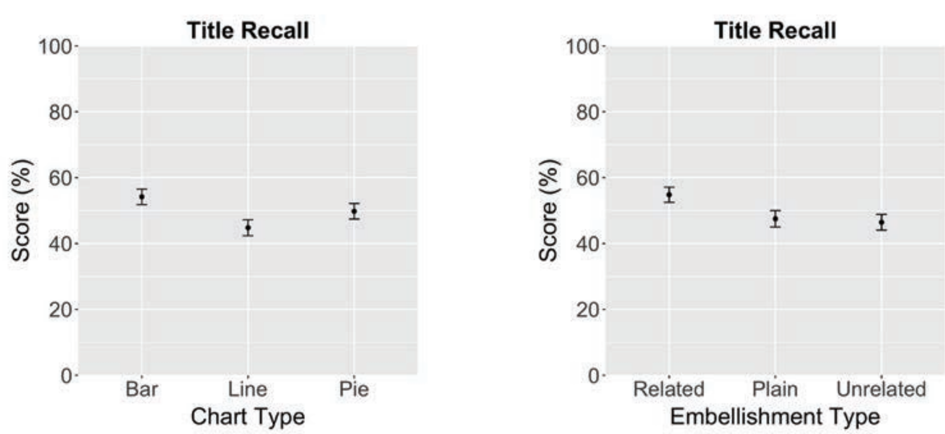

Figure 3 / Mean scores for title recall grouped by chart type (left) and embellishment type (right). Error bars show standard error. Bar charts scored significantly higher than line charts. The score of the related charts had significantly higher scores than unrelated charts and almost significantly higher scores than plain charts.

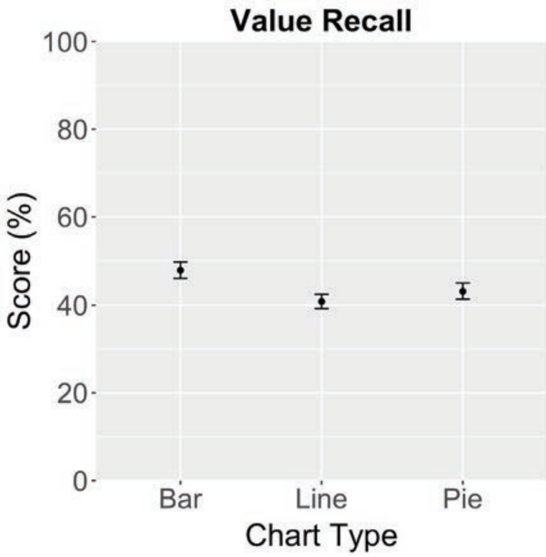

Figure 4 / Mean scores for value recall grouped by chart type. Error bars show standard error. Bar charts scored significantly higher than line charts.

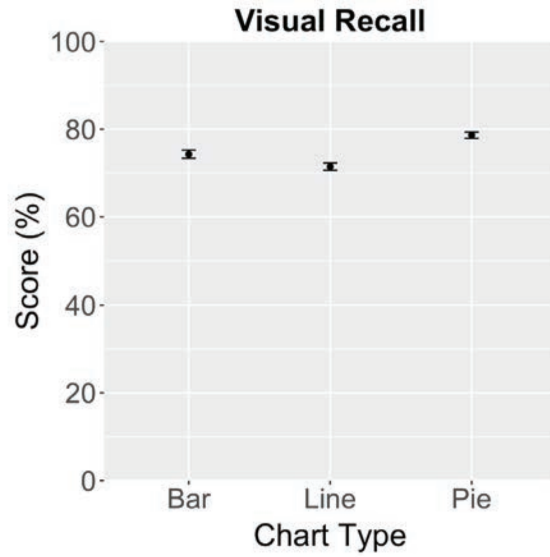

Figure 5 / Mean scores for visual recall grouped by chart type. Error bars show standard error. Pie charts scored significantly higher than bar and line charts. Bar charts scored significantly higher than line charts

For visual recall, participants were asked to manipulate a value of either a category or point on the chart to match their recall of the chart shape. We scored their final manipulation by taking the distance from the correct answer divided by the range of possible value to produce a value between zero and one. There was a significant main effect in chart type, with $F(2, 156) = 24.77$ and $p < 0.001$. Pie charts performed significantly better than both line charts and bar charts with $p < 0.001$ for both. Bar charts performed significantly better than line charts with $p < 0.05$ (see Figure 5). There were no effects of embellishments on recall.

For theme recall, participants were shown an unlabeled and untitled chart and asked to select the theme from a list of choices. The score for this task was a count of the number of correct selections. There was a significant effect in embellishment type with $F(2, 160) = 112.53$ and $p < 0.001$. The descending order ranking of the scores was embellished with context, plain, embellished without context (see Figure 6). Related charts scored more than plain and unrelated, both with $p < 0.001$, and plain had higher scores than unrelated with $p < 0.001$. This may be the result of participants recalling the imagery more than the actual subject.

There was a significant effect of chart type on the time it took to complete session one with $F(2, 156) = 3.31$ and $p = 0.009$. Overall, pie charts took more time to answer than bar charts ($p < 0.05$). The average times for title, value, visual, and theme recall tasks were 1.68, 5.94, 3.77, and 3.74 minutes, respectively. There was a

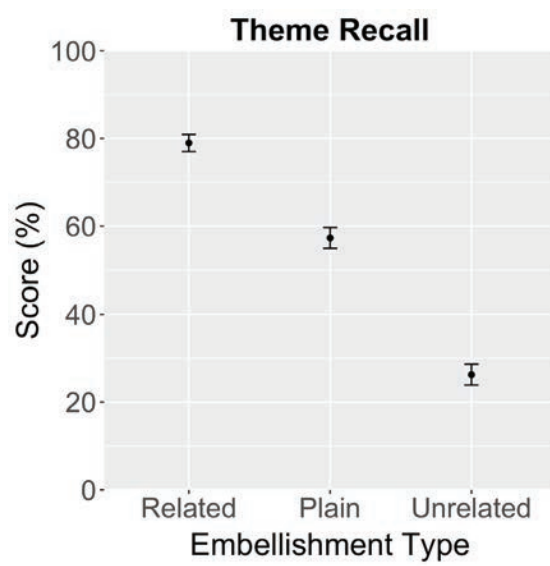

Figure 6 / Means scores for theme recall grouped by embellishment type. Error bars show standard error. Embellished charts scored significantly higher than plain and unrelated charts. Plain charts scored significantly higher than unrelated charts.

significant effect of chart type on the time it took to complete the theme recall task with $F(2, 156) = 3.71$ and $p = 0.027$, but no significant pairwise differences among chart types from post-hoc testing.

DISCUSSION

In this section, we discuss how the results relate with respect to the hypotheses, and we also discuss study limitations and implications for visualization creation tools.

Revisiting the Hypotheses

The results from the study can be used to evaluate our hypotheses described in the experiment section. We aimed to collect further empirical data about how different types of embellishments influence the memorability of different types of chart information. To help simplify the measures from the four tasks, we consider their organization into two main categories: chart topic (title recall, theme recall) and data details (value recall, visual recall), though these are not always clearly separate elements. We found that embellishment types had a significant effect on topics based on the results of title recall and theme recall scores. On the other hand, the study failed to detect differences for the data detail tasks. These results support hypothesis H1, as well as align with prior research on memorability (Bateman et al., 2010; Borkin et al., 2013; 2016). This finding also partially provides backing for the claim that embellishments can be effective for reinforcing a message about a data topic, though information about the message must be related to the data values, title, and theme. Further experimentation is needed to clearly evaluate memorability of the directionality of a message. It is not the case that the simple addition of any decorative elements will automatically increase memorability.

The opposite effect for relevant vs. unrelated embellishment is clear. Related embellishments significantly reinforced memory of chart topics, while unrelated embellishments negatively affected memorability. Thus, relevant embellishments can have a positive effect on memory, but only if the embellishments are chosen well. A probable explanation is that memorability of the embellishments overrides the memorability of the actual informational content. This indicates that a poor choice for supplemental embellishment ("chart junk") can be distracting or interfere with memory if the viewer does not perceive a relationship between embellishments and topic. Furthermore, this finding establishes a baseline for future studies, which may systematically vary facets of relevance with respect to design elements in a given visualization.

Regarding hypothesis H3, the differences between color and black-and-white images was clearly minor in our chart set and evaluation. There was no significant effect of color type on charts; thus, the results do not contribute evidence in support of H3. Our study did not account for the use of appropriate or unusual coloration in relation to the embellishment design, which would also be interesting to consider along with the study of relevance.

We also found that chart type played a role in memorability. For all tasks except theme recall, chart type had significant effects on recall. These results provide evidence in support of hypothesis H2 by suggesting that chart type is influential for memory of chart information. However, there was little consistency with which chart type (line, pie, and bar) were more or less memorable for the different recall measures. For example, bar charts were significantly more memorable than line charts for title recall, value recall, and visual recall. Pie charts were more memorable than both line charts and bar charts in terms of visual recall. The high memorability of pie and bar charts for visual recall might suggest that viewers had an easier time remembering visual ratios, as that is largely what pie and bar charts represent, rather than line shape or trends. The lack of effect of chart type on theme recall may be similar to prior findings that common chart types may be less memorable than unique visualizations (Borkin et al., 2013). In other words, because the experiment only included three basic chart types, their designs were not interesting enough to impact thematic memory.

Towards a Greater Understanding of Memorability and the Designers' Role

A number of studies have addressed the topic of memorability in infographics and embellished charts.

While some of these studies (Bateman et al., 2010; Borkin et al., 2013; Li and Moacdieh, 2014) look at illustrative graphics and elaborate infographic embellishments more similar to Holmes (1984), others have investigated more minor manipulations and stylistic enhancements (Borgo et al., 2012; Haroz et al., 2015). Our research tends toward the side of more limited embellishments in an attempt to preserve the underlying visual encodings of data, though our custom created embellishments may provide a somewhat greater degree of enhancement while maintaining high experimental control for the presented study. Overall, the complexity of the design space and range of variations in study designs can make it difficult to directly compare the results of different investigations on the topic of memorability.

One of the primary contributions of our research is the controlled comparison of fundamental chart types. While other studies have considered a variety of chart types from existing available infographics, our method and hand-crafted data set allowed a more controlled approach. The results demonstrate greater visual memorability of pie charts compared to bar and line charts, whereas bar charts facilitated better memory of information values. This is an important finding that might suggest people fundamentally allocate attention differently when interpreting different chart designs. Perhaps because bar charts support more accurate perceptual judgments due to the use of length encodings (Cleveland and McGill, 1984; Heer and Bostock, 2010; Saket et al., 2018), participants were more easily able to extract the value details for retention. Alternatively, perhaps pie charts are viewed more informally, or they may encourage more attention to the visuals holistically rather than to precise judgments, which may explain why pie charts are more visually memorable. As another explanation, it may be possible that pie charts or bar charts were easier to visually interpret during the visual recall measure rather than the representation itself necessarily being more memorable; further research is needed for a deeper understanding of possible factors.

Our experiment assesses recall after a significantly longer period of time than some memorability studies such as Borgo et al. (2012) and Haroz et al. (2015). Our study, with one week between sessions, is more similar to Bateman et al.'s (2010) approach of 2 – 3 weeks between sessions. Similar to our findings, Bateman et al. investigated a variety of aspects of chart understanding, but no evidence that embellishment were better for memory of information beyond the designer's primary intended message was found. This result is most similar to our findings for theme recall, though we also contribute further information about relevance about embellishments, and we also found effects for title recall.

The study by Haroz et al. (2015) resulted in partially similar findings regarding relevance of embellishments to the data topic, but their study's emphasis on "close-but-not-quite-matching" embellishments offers the potential for a different type of distraction or confusion if viewers mix up specific data items with the embellishment. Our study's use of related and unrelated embellishment takes a more extreme approach to verify that the unrelated versions were clearly not related to the topic. Importantly, the negative results of unrelated embellishments hold true across studies, suggesting that the effects observed by Haroz et al. were likely not due to interference from "class similarity." Together, our results suggest the reduced memorability of chart information may be due to overall distraction and difficulty in separating the visuals from the data, and our study demonstrates that these the negative effect of unrelated visuals persisted over a one week period.

Following the existing body of research, our study found that chart design can affect memorability, but different studies evaluate different aspects of memorability and chart information. Our separation of value recall, title recall, visual recall, and theme recall tasks help separate different types of information. We can examine consistencies by cross-referencing studies. Borkin et al. (2016) found that presence of a chart title contributes to greater memorability in general, and our results demonstrate related embellishments did improve title retention. The assessment of "concept grasping" by Borgo et al. (2012) was similar to our assessment of theme recall, and the findings align as previously discussed. Recall of chart value details is difficult, and our study did not find differences due to the embellishment conditions. In contrast, Haroz et al. (2015) did observe significant differences in value recall from embellishments, but their tested visual designs involved limited numerical ranges and discrete values shown by a corresponding number of representative icons. It may be the case that such representations are more visually memorable, as perhaps participants were recalling the chart appearance rather than completely encoding the data values. Given the shorter period between exposure and recall, we expect a visual recall strategy may be feasible. In our own study, participants demonstrated fairly high performance on the visual recall task even one week later, but it was not sufficient for supporting recall of details. Future studies may examine the possibility that participants are encoding shape or relational characteristics of the visualization, and how design choices may impact such encodings.

Implications for Graphic Creation Tools

The results of this paper suggest that design enhancements alone are not necessarily sufficient to positively influence human-centered measures such as memorability. These results may therefore hold implications for the feature sets of graphic authoring tools. Specifically, in the information visualization community, multiple recent initiatives have led to significant advances in visualization creation and authoring tools (Kim et al., 2018; Liu et al., 2018; Ren et al., 2018; Xia et al., 2018). For example, Liu et al. (2018) developed Data Illustrator, a software that combines vector editing tools like Adobe Illustrator with data-bindings to enable the creation of complex, custom visuals. The results of this research may imply that such functionality could be extended to ensure that users have the ability to craft embellishments that align with their particular data domain. More broadly, the recent increase in visualization authoring advancements may point to a need for more robust experimental methodologies. As more creative representations of data become possible, quantitative evidence is needed to determine whether particular compositions of visualization styles and embellishments lead to positive outcomes for the audience.

LIMITATIONS

In this study, we used base data from the MASSVIS dataset and modified the visual representations to meet the needs of the experiment. Deviating from the original design of the infographics and visualizations altered the style, tone, and message of the source. As such, our experiment does not claim to use real infographics or informational signage; this was intentional and necessary to maintain experimental control of our independent variables. Real infographics are often more complex and involve additional types of embellishment beyond the templated decoration formats included in our study. Embellishments in our experiment were limited to additions of imagery within and around the visual data encodings of each chart. Moreover, since we purposefully maintained the mapping between visual encodings and data values across conditions, our experiment did not consider more advanced types of stylistic manipulations that would have altered the data presentation or "lie factor" (Tufte, 1983). Such manipulation or deception was beyond the scope of this research, though the topic has been investigated by others (see Correll and Heer, 2017a; Pandey et al., 2015). Further research is needed to gain a broader understanding of memorability of visuals and information across a variety of media formats, such as web, signage and print, in the wild.

CONCLUSION

Our study tests the effects of graphical enhancements, color, and chart type on memory of chart information over the period of a week. For this particular study, the enhancements were supplemental embellishments that did not manipulate the fundamental chart design or data encodings. Embellishments relevant to the data significantly helped in the recall of title and thematic elements, and unrelated embellishments were significantly detrimental to memorability. Having this knowledge, we can exploit more effective ways in conveying both the message and visual displays. Future work might include understanding the effects of interactions and embellishments that alter data values to strengthen the communication of an intended message.

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Signage Form and Character: a window to neighborhood visual identity

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Abstract /

Signs contribute significantly to the visual identity of neighborhoods, often representing the interplay of the collective social, political, cultural and economic values of the people who live and work there. On-premise signs displayed on building facades and storefronts in the neighborhood business district of three distinct neighborhoods in Cincinnati, OH are examined to document the typographic styles and form (material, size and scale, color, etc.) of the signs. An empirical photographic survey is employed for elevation mapping, to record the full range of on-premise signs in each neighborhood business district. Over 150 on-premise signs are documented and analyzed. Our findings suggest that as neighborhoods get gentrified, particularly with non-local capital and investment, the signage form and character, represented by the typeface, shape, material, illumination and other properties, become more homogeneous, replacing the variety of typefaces as well as signage form. The study found that the signage used by the chain stores and other new businesses that are not place based to be mostly all-capitalized, three-dimensional, back-lit, and having other properties that are undifferentiated, generic, and visually monotonous.

Keywords /

storefront signage; typeface, neighborhood businesses; visual identity; communication.

SIGNAGE AS COMMUNICATION

Signage is an important component of place-based communication system and on-premise signage contributes significantly to the experience of place, particularly commercial space, such as a neighborhood business district or main street. Signage quintessentially represents and mediates between what Zukin (1995) calls the visual economy of the landscape and market culture. Signage acts as material traces, providing a direct spatial semiotic—a visual sociology of place (Krase and Shortell, 2011). Beyond their commercial, regulatory, and sensory visual value, signs are symbols: they communicate socio-cultural and political messages.

SIGNAGE FORM AND CHARACTER

Types and fonts have personalities, traits, and specific qualities. These personalities and qualities convey messages beyond what is expressed within the text of the sign. Scholars and practitioners in marketing, consumer psychology, and communication, and its numerous sub-fields have been studying this for long; almost a century ago, Proffenberger and Franken (1923) identified five atmosphere qualities of fonts: cheapness, dignity, economy, luxury, and strength. More recently, for example, Kostelnick and Roberts (1998) depicted Times New Roman as "bookish and traditional," Bodoni as "dramatic and sophisticated," and Goudy as "corpulent and jolly." Through the personalities and qualities of type, signage then becomes a source of messages and meanings that serves as a form of cultural expression. In his 2012 work *Characters: cultural stories revealed through typography*, Stephen Banham meticulously depicts the signage and typography of a city to present an exuberant collection of quirky, poignant, and often funny stories. Called a "typographic evangelist" by UK design journal *Eye*, Banham reveals how typography is a rich form of cultural expression, redefining the perspective of our surroundings. Typography, used in signage and other forms on public and private buildings, along roadways, on transit vehicles and stops, in graffiti, advertisements, storefronts, and anywhere visible to us, is a form of intentional communication.

SIGNAGE AND NEIGHBORHOOD BUSINESS

Neighborhood businesses use on-premise signage for communicating their presence and attracting customers. At the same time, on-premise signs give businesses an opportunity to communicate identities and values which help them connect with certain types of consumers. In the e-commerce economy, many businesses are paying close attention to signage in order to distinguish their businesses as places offering unique, tangible, and rich experiences. Operating in a definite physical space, many of these businesses pay special attention to curating their goods, services, and all communication, including signage, to establish a localness. In doing so, many neighborhood businesses carefully understand and determine the values and preferences of the local neighborhood communities, many of which serve reliable customers and dedicated supporters. Collectively, on-premise signs displayed on building facades and storefronts in neighborhood business districts provide us with a window into the visual identity of the neighborhood. This visual identity is the representation of the interplay of the collective social, political, cultural, and economic values of the people who live and work there.

Research Focus

By methodically examining and analyzing the collective patterns of signage on neighborhood main streets, this study examines one aspect of the visual identity of the neighborhood revealed through its signage landscape. Specifically, this research examines neighborhood visual identity through an analysis of the form and character (typography, materiality, dimensionality, size and scale, color, and more) of on-premise signage used by businesses on neighborhood main streets. Consequently, the research contributes to our understanding of how sign's words, type, and letters act as artifacts and convey meaning in an urban environment, while also contributing to a neighborhood's sense of place.

METHODS

Selection of Neighborhoods

Three neighborhoods in Cincinnati were selected for the study; the neighborhoods were chose for both their commonalities and the variations. Each neighborhood has pedestrian-oriented commercial streets, with low vacancy rates where businesses display signage. The neighborhoods provide quality infrastructure and conditions for walking to the commercial street as well as ample on-street and lot parking options in the vicinity. Simultaneously, each of these neighborhoods is physically, culturally, and socio-economically unique and substantially different from each other.

Clifton is a historic neighborhood that is diverse, artistic, cosmopolitan, and eclectic. A typical streetcar suburb, it has an urban village feel with historic apartments, homes and mansions along tree-lined streets, many of which are lit by early 20th century gaslight lamps. The neighborhood is home to families, young and old, educators, researchers, artists, professionals, and university students. Ludlow Avenue, the main commercial street, is the center of the neighborhood and supports a collection of shops that offer a variety of retail, eating and drinking establishments, and even a historic theater, all of which cater to the daily needs and wants of the surrounding community (Figure 1).

CUF, an acronym for the neighborhood that represents Clifton Heights, University Heights, and Fairview, is located adjacent to the University of Cincinnati. The parts of the neighborhood closest to the university are predominantly rental properties providing off-campus student housing, with many eating and drinking establishments and convenience stores that are oriented towards students' needs. Most of the historic Clifton Heights Business District has been redeveloped into a mixed-use district with new housing and businesses that cater to university students (Figure 2).

Hyde Park is one of the most affluent neighborhoods in Cincinnati and therefore one of the most exclusive. Many large estates, mansions and stately houses with manicured lawns make up this largely residential neighborhood that has a predominant historic suburban feel; it is home to families considered "old money." At the center of the neighborhood is Hyde

Figure 1 / A view of Ludlow Avenue, the main street of Clifton in Cincinnati, OH.

Figure 2 / A view of Calhoun Street, one of the commercial streets of CUF in Cincinnati, OH.

Figure 3 / A view of Hyde Park Square, the business district of Hyde Park in Cincinnati, OH.

Figure 4 / An example of a part of Ludlow Avenue, the main street of Clifton in Cincinnati, OH where each on-premise sign was accurately sized, located and prominently displayed on the elevation.

Figure 5 / Accurately sizing the on-premise signage. An example of a part of Ludlow Avenue, the main street of Clifton neighborhood in Cincinnati, OH.

Park Square, a charming shopping area with a variety of upscale boutiques, high-end eating and drinking establishments and other chic businesses (Figure 3).

Study areas

Only on-premise signage installed on storefronts or building facades on the main commercial street of the neighborhood were examined. These included the formal and intentional signage commissioned by the owner of the building or the business owner, but temporary signage, art murals, or graffiti were not included in the study. Over 150 signs were documented in the three neighborhoods.

PROCEDURES

Each of the three commercial streets were visited during daytime in summer and fall of 2017 and documented by one of the authors. A systematic photographic survey was employed for elevational mapping to record the full range of on-premise signage along the commercial street of each neighborhood. A GIS map of the street was traced and verified with on-site measurements. Canon 60D DSLR camera on a tripod was used and photographs were taken from the opposite side of the street and fixed distance away to achieve an accurate elevational aspect-ratio for photo-stitching. Close-up and wide-angle photographs were also taken to condut a signage form and character analysis. To generate the final images, photographs were imported in Adobe Photoshop to adjust and edit white balance, darkness, and minor distortion in perspective. Using panoramic photo-stitch, systematic scaled façade elevations were created for both sides of each street. Each sign was accurately sized, located and prominently displayed on the elevation (Figure 4). Lastly, Adobe Illustrator, with software plugin CADtools 12.1.1, was used to create data charts, labelling, and to measure elevational heights, distances, and calculate surface area. The percentage of sign area on the storefront or façade was measured and illustrated (Figure 5).

Once all signs were identified, typographic elements were determined and tallied in the following categories: sans-serif and serif typefaces, and further into their subcategories (Lupton, 2004) of old-style, transitional, Tuscan or decorative, Egyptian or slab serif, geometric, humanist, calligraphic, custom style, etc. For each sign the signage was further categorized by word-count, and uppercase vs. lowercase. Materials, color, and other customizations were documented, along with any use of neon, backlighting, or three-dimensionality of the letters or the whole sign (Figures 6 and 7).

FINDINGS

Ludlow Avenue, Clifton

A wide range of signage creates an image of visual variety for the businesses on Ludlow Avenue, the commercial main street in Clifton. Calligraphic, decorated, and custom on-premise signs dominated the signage landscape (Figure 8).

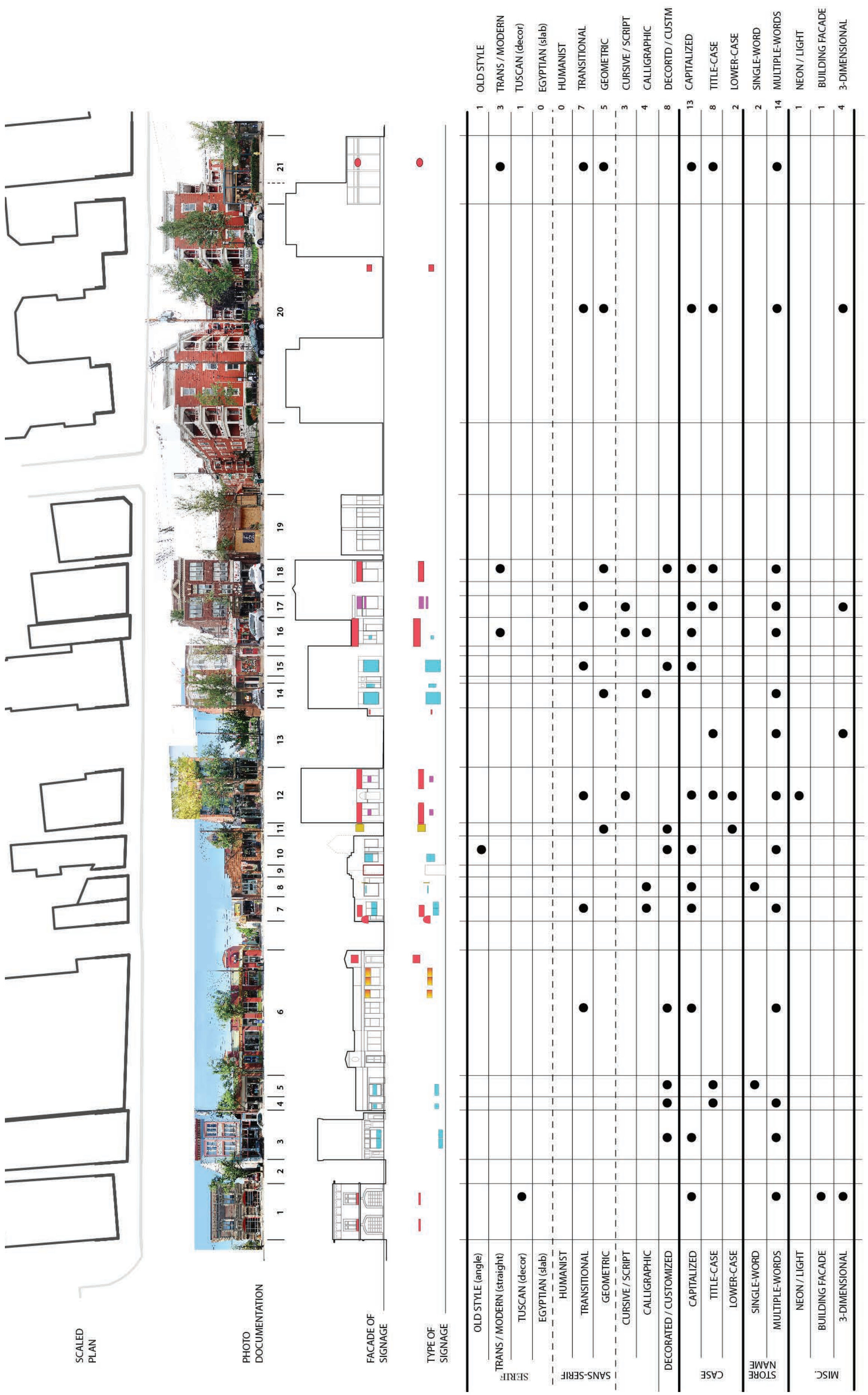

Figure 6 / Categorizing the on-premise signage by elements of form and character. An example of a part of Ludlow Avenue, the main street of Clifton neighborhood in Cincinnati, OH.

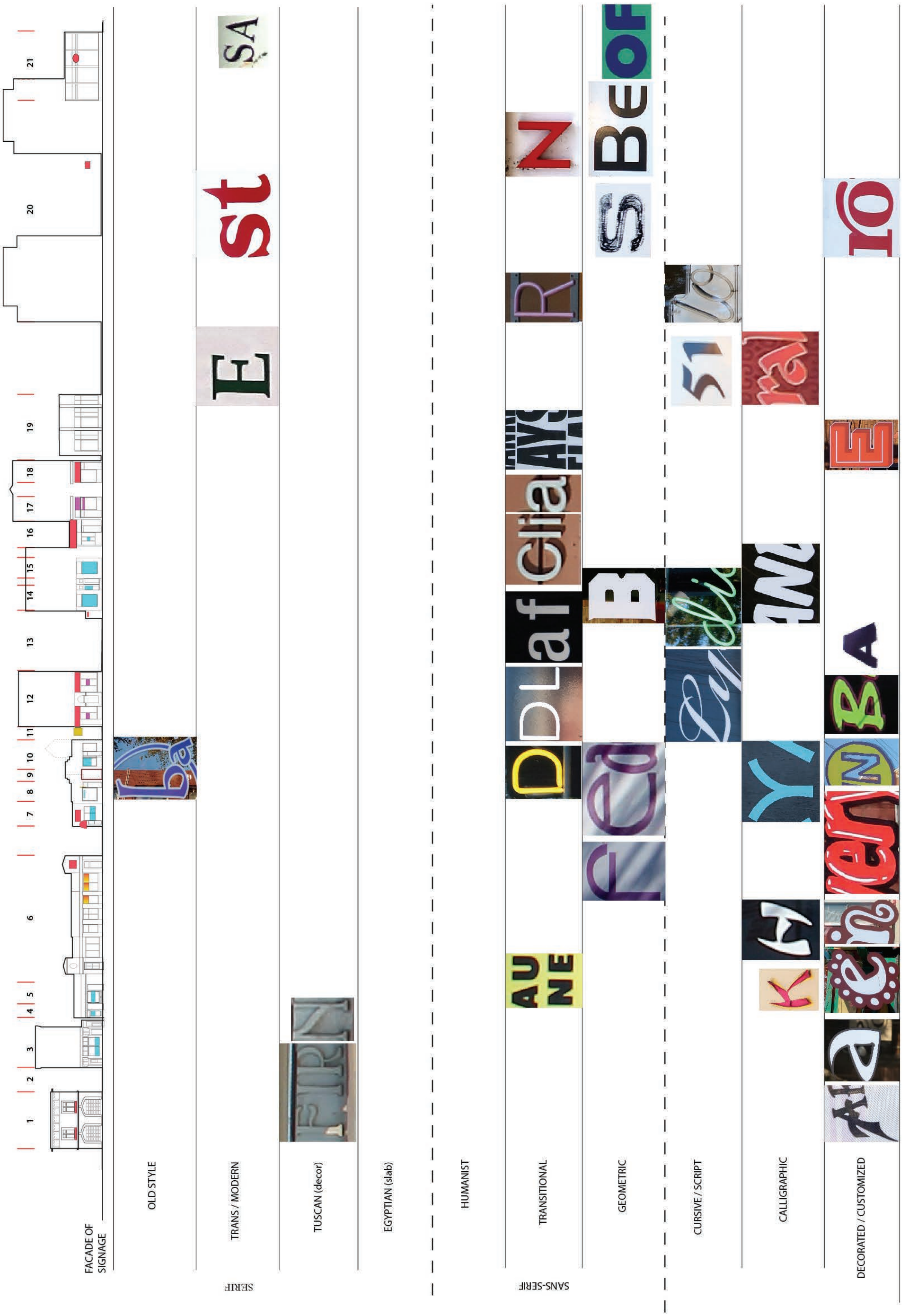

Figure 7 / Categorizing the on-premise signage by elements of form and character. An example of a part of Ludlow Avenue, the main street of Clifton neighborhood in Cincinnati, OH.

Figure 8 / Calligraphic, decorated and custom on-premise signs dominated the signage landscape on Ludlow Avenue, Clifton.

Figure 9 / Signs on businesses in Clifton display a diversity of typefaces including Geometric, Transitional San-Serif, Calligraphic lettering, etc.

The typography of signs ranges from Tuscan to Transitional, along with Old Style Serif to Geometric. Within the Geometric, Transitional San-Serif and Calligraphic lettering, there is plenty of diversity of typefaces, color, and size (Figure 9). Although there is a high preference of Transitional San-Serif typefaces (45%), signs on Ludlow Avenue display a variety of many other types.

There is significant amount of cursive lettering (18%), and 20% of signage is calligraphic, but 34% are decorated and customized typefaces, which is the highest percentage across the documented neighborhoods. There are numerous international restaurants and boutique stores, where typeface choices and styles reflect the tradition of the respective national or cultural background of the business owners.

The majority (75%) of signs are flat, painted or printed on vinyl, with only 14% signs being neon, the least percentage of the three neighborhoods. Overall the signage landscape is internationally diverse, eclectically local, and rooted in its context. The visual identity created by this signage landscape aligns well with the attributes of Clifton as a welcoming, inclusive, tolerant, and diverse neighborhood.

Calhoun Street, CUF

Calhoun Street in the CUF neighborhood is actively undergoing transformation, as old buildings are being replaced by newer high density development. This revitalization is also changing the types of businesses on the commercial street. The west side of Calhoun Street, reflects previous establishment and retains several small local businesses showcasing a high variety of signage that uses numerous typefaces as compared to the new businesses on the east side of the

Figure 10 / Compared to the local businesses (Drunken Bento / Sushi) on the west side of the Calhoun Street, the new dormitories and chain stores (Mr. Sushi) create a stark contrast with the typeface choices, materials and sizes.

street. Compared to the local businesses on the street's west side, new dormitories and chain stores are in stark contrast regarding typeface choices (Figure 10). In these newly opened businesses, there is only the trace of calligraphic or Tuscan typography in one store.

Further, the signage accross all the new development shows little variety in scale, contrast, and texture. 58% of the typefaces used by the businesses here are Traditional Sans-Serif and Transitional ones, collectively resonating "new" business and chain stores, but resulting in a monotonous visual image. Unlike the balanced mix of both Sans and Serif in the older retail stores on the west, the new developments use fonts like Helvetica, with its uniform extrusion and upright Sans-Serif shapes. There is also a gradual transition from the west, to the east, in regards to the increase in three-dimensional lettering either attached to the building surface or the canopy signage. Across the entire street, 50% of signs embrace either a neon flair or backlit hoardings, almost 55% of those are 3-dimensional pliant lettering, all of them are on the newly developed part of the street. To add to the monotony, 81% of the signs, typically brand names, are all-capitalized. Only 4% of the signage are single-word signs, whereas 70% are multiple words.

In order to compete with the new businesses, bigger and better signage have also adorned the older part of the commercial area. Overly populated with information, these older and more locally owned businesses now display signs that are oversized and crudely overpainted, yet forming an essential part of the local charm (Figure 11).

Figure 11 / Some older and more locally owned businesses on Calhoun St. in CUF are displaying oversized and crudely overpainted signs.

Hyde Park Squre, Hyde Park

Many of the exclusive, high-end businesses in historic Hyde Park Square evoke a sense of time and aristocratic flair by using Old Style Serifs that first emerged in Europe in the sixteenth century. 30% of typefaces are in Old-style and 20% are Transitional/Modern without any Slab Serif typeface. These typefaces are used on historic buildings, expensive cafés and restaurants, realty companies, and other exclusive stores (Figure 12).

Almost one-third of typefaces are either Geometric or Cursive, aligning with the expensiveness and exclusivity of businesses. San-serifed, slightly rounded Geometric and Humanistic styles are predominant. Geometric Sans Serifs, like contemporary Modern-Serifs, connote simplicity, with primary shapes accentuating the formal attributes, relating to functional, modern, or minimal (exclusive). They have letterforms based on simple geometric shapes — most popularly the circular 'O' and triangular 'V' — and address very minimal intervention of irregular/grotesque shapes and encourage optical repetition in typography. Their ultra-modern shapes often compromise legibility at smaller sizes or with tracked typographic layout (bigger spaces between letters in a word). Structured and minimalistic (thin and geometric) typefaces used in the storefront signage directly connote not-everyday and exclusive (Figure 13). More than half of the signs used by the businesses here are capitalized with multi-word names.

Figure 12 / Old Style Serif typefaces are used on historic buildings in realty company signs, and other exclusive retail stores.

Figure 13 / Structured and minimalistic (thin and geometric) typefaces used in the storefront signage directly connote 'not-everyday' and 'exclusivity'.

DISCUSSION

Our empirical research findings from on-premise signage used by businesses on neighborhood commercial streets provide insights into several aspects of signage, particularly as it relates to neighborhood identity. First, the collective image of on-premise signs used by businesses in the three neighborhoods showcase very distinct visual identities. Second, the businesses in a neighborhood commercial district with even more disparate on-premise signs create a singular identity (or two) that can be examined and critiqued.

Clifton's commercial street comprises several diverse small businesses, including many representing different cultures and international affiliations, that use diverse typeface choices and styles reflecting their respective national and cultural background. The variety of signage forms a coherent language of inclusiveness and diversity that appears more approachable for the diverse set of people that live and visit Clifton, including the many students studying at the University of Cincinnati, located nearby. The visual identity created by this signage landscape aligns well with Clifton's desire to be a welcoming, inclusive, tolerant and diverse neighborhood (Figure 14).

In contrast, on the signs in CUF, through their the typeface, material, dimensionality, size, and color creates a non-place global identity likely to communicate with and attract the young students from the University who may live, eat, and shop on the street. Collectively, these signs project a clean and streamlined aesthetic that is free from any connection to its location and is proudly ageographic (Figure 15). This signage landscape clearly suggests businesses built on capital that is mobile and transferable. This common corporate image, along with a disinterest with its spatial context, projects a cold and homogeneous aesthetic.

Although a very different neighborhood compared to Clifton, the signage landscape in Hyde Park similarly mirrors the neighborhood's desired identity. The signs have a high typographic variety, but the use of Old Style Serifs and contemporary minimalist typography exhude an air of sophistication and exclusivity (Figure 16). The oft-used geometric typeface styles address very minimal intervention of irregular/grotesque shapes and encourage optical repetition in typography. As a primary communication medium, signage delivers a clear message to the reader that the space, goods and services in this business district come at a price and are not for all. Simultaneously, the attempt at unifying identity through standardized green canopies project membership-only "country club" vibe.

Figure 14 / The visual identity created by the overall signage landscape aligns well with the welcoming, inclusive, tolerant attributes of Clifton.

Figure 15 / Examples of clean, homogeneous and proudly ageographic signs with corporate and streamlined aesthetic on Calhoun St. near the University of Cincinnati campus.

Figure 16 / Amidst the typographic variety in Hyde Park Square signs, the use of Old Style Serifs and contemporary minimalist typography project an air of sophistication.

Limitations of Study

Like much empirical work, this research has limitations resulting from time constraints. In our research, each commercial street was visited only during daytime and examining the on-premise storefront and facade signs after dark would have likely provided other readings that are distinct from the daytime where size, dimensionality, color, typeface, and materiality dominate. Our research was also limited to empirical visual studies of on-premise signage. Surveys and interviews with the business owners would create a better understanding of the intent behind and choices of size, location, and typography. Surveys and interviews could also explain what support or limitations the business owners faced as they worked in the context of their respective business associations, neighborhood covenants, residents' associations or other governing bodies.

CONCLUSION

In this paper, we have reported the findings from a comprehensive documentation, analysis, and interpretation of typographic taxonomy of on-premise signage on three neighborhoods' commercial streets in Cincinnati, OH. To the best of our knowledge, this method of examining on-premise signage at this level of detail has never been applied before. This is likely because such an empirical inquiry requires a vast investment of time to conduct extensive field work, documentation, and analysis.

By examining the typography of signs in more imageable and public areas of the neighborhood, such as the commercial street, we were able to get a glimpse of the neighborhood's visual identity. This identity, visible through the typographic taxonomy of on-premise signage presents a reading of the neighborhood. Our research shows that signs can act as powerful communication systems for relaying and representing community values, social practices, and economic trends. Perhaps more importantly, we are finding that reading the neighborhood through signage taxonomy has numerous other benefits for urban designers and planners. This reading elevates the understanding of the neighborhood beyond mere visual and sensory aspects (that occurs as a first reading of signs), to the more meaningful understanding of neighborhood strength and opportunities. Signage taxonomy acts as a powerful evaluative tool that represents the neighborhood's place identity by revealing aspects of economy, power, status, cohesion, and diversity.

ACKNOWLEDGEMENTS

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Visual Access Formed by Architecture and its Influence on Visitors' Spatial Exploration in a Museum

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Abstract /

A visitor's experience in space is one key research topic carried out by researchers from multiple disciplines. Regarding the architecture of a museum, research has shown that it is linked to a visitor's spatial experience in that space. These spatial experiences are relating to aspects such as a visitor's memory of location, feeling in the space, and making sense of exhibitions. Following the suggestion that architecture influences a visitor's spatial experiences, we introduce a study addressing the accessibility of one's vision, named visual access, formed by the architecture and its association with visitor's exploration pattern. Additional approaches including observation and interviews were carried out to address this question about how the architecture influences visitor's exploration in a museum. Results show that direct visual access has a greater influence than physical distance in a visitor's decision for initial exploration of a museum. In addition, these results are also used to address the pattern of exploration taken by visitors.

Keywords /

spatial exploration; museum; visual access; visibility; architecture.

INTRODUCTION

A visitor's spatial experience in a museum is a specific type of wayfinding behavior. In general, wayfinding can be characterized into three major types: *quest*, *commute*, and *explore* (Allen, 1999). *Quest* implies that someone tries to reach an unknown destination from a familiar point of origin. *Commute* indicates the movement of a person between two familiar locations and is most likely a repetitive activity. *Explore* indicates movement with no particular goal of reaching a pre-determined location in an unknown environment, which most closely resembles the spatial experience of someone visiting a museum for the first time. Researchers are interested in visitors' spatial experiences in a museum, as it provides valuable feedback regarding organization, placement, and attraction when planning exhibitions and drawing in visitors. For example, there are existing investigations describing the influence of a museum's layout on visitors' memory of the exhibitions (Krukar, 2014). Importantly, research from the perspective of museum curatorship addresses the sense-making of visitors' exploration of museum exhibitions (Schorch, 2013). Specific to a visitor's embodied experiences, researchers like Tzortzi (2017) investigate the understanding of space by linking the spatial and visual structure of that space. Following this suggestion, this study investigates how a museum influences the visitors' exploration of space through their visual access, as shaped by the physical structure.

Studies have suggested that the physical structure of an environment can influence a person's spatial experiences. Lynch (1960), for example suggests the difficulty of a visitor's spatial experience in an environment is associated with legibility, the easiness of understanding and finding one's way in that environment. The legibility of a space is "the property of the space that allows a situated or immersed observer to understand it in such a way as to be able to find his or her way around it" (Bafna, 2003; 26). Legibility is present in three aspects. The first aspect refers to how easily a person can differentiate sections in the environment, the second to a person's access with vision in the environment, and the third to the complexity of the environment's spatial layout. In this study, we are interested in the role that visual access has in influencing a visitor's spatial exploration of a museum. We chose to address visual access in this study, not only because of the visual structure which is associated with one's spatial experiences in museums, but also because of the characteristics of a museum operating within a large space (Tzortzi, 2017); the museum space that we refer to is comprised of multiple levels. Normally, a large museum provides an open space concept, so that layout complexity within an exhibition is not particularly extreme, as the space is needed for many visitors. Hence, layout complexity can be challenging to first-time users.

Given the uniqueness of individual collections in museum exhibitions, a visitor uses these cues to move along and differentiate each space; varying noticeable elements, such as color, size, form, or architectural style, can further help wayfinders distinguish locations and between exhibits (Evans et al., 1984). Therefore, we first aim to focus on the visual access formed by the museum's physical structure, as it may have the most influence on a visitors's spatial exploration. This includes information such as the order in which collections are visited and other spatial experiences.

The rest of this paper is organized as follows: In the Related Work, we review the concept of visual access and its potential influence on a person's spatial experiences in space. In Methods, we first introduce the museum chosen as our study site and the designed approaches for our assessment. Results present the analyses of the space in terms of its visual access and our collected data in the museum. Discussion presents the role of visual access and ways to improve visitors' spatial experience. We also evaluate the limitations and suggest potential avenues for follow-ups to this work.

RELATED WORK

Architecture plays an influential role in users' spatial experiences. It is common that if a person can easily differentiate areas of an architecture, they will be able to recognize locations while finding their way to their destination. The form of architecture contributes to the degree of differentiation, so a museum where visitors can distinguish areas contributes to the legibility of the museum's overall architecture. In addition, visual access within an environment plays a critical role in the visitor's wayfinding behaviors; visual access suggests the extent of visibility that a person can reach from a single location. The higher visibility of a place, the better visual access a person has, and previous work has linked visual access with a person's spatial experiences in a place (Gärling, Lindberg, and Mäntylä, 1983; Wiener and Franz, 2005; Hölscher et al., 2009). For example, good visual access, can enable a person to immediately find an area with an overview of surroundings, while also locating a good place to hide (Wiener and Franz, 2005). It is an effective approach, as both the best hiding and viewing places are directly associated with unobstructed visual access.

In this vein, an isovist represents the visual breadth from a single vantage point in a physical environment; it considers the convex shape of a perceptible space within 360° of a standing point (Benedikt, 1979). The convex polygon representing an isovist is determined by the boundary of an environment and the areas where vision is unobscured. While the original isovist concept assumes that a person would have a complete viewing angle of 360°, Hölscher et al. (2009) adapted the measure that only an isovist in the person's facing direction should be considered to accurately simulate a person's viewing experiences. The improved concept is considered a partial isovist, with 120° representing a human's natural vision span. An isovist only represents the visual access at one vantage point, so it does not provide an overview of an entire space. Turner et al. (2001) introduced an additional component to the isovist concept, visibility graphic analysis (VGA), which assumes all possible standing points by breaking the entire environment into a series of grids. The accumulation of isovists within each individual grid forms an overall representation of visual access in a space and is therefore a more complex representation than what is produced by using a single isovist. These accumulated results tend to show areas of best and relatively poor visual access simultaneously, and studies have been carried out using this method to predict visitors' attention to specific exhibitions (Krukar, 2014). This work utilizes and adapts the partial isovist concept at a museum's entrance and then conducts VGA in individual exhibition halls, associating them with observations of visitor exploration and interviews.

METHODS

This study consists of analyses of both physical environments and human wayfinding behaviors. We first introduce the selected museum and continue by describing the physical environments through quantitative methods, and the design of behavioral experiments to assess wayfinding decisions.

Luo Zhongli Art Museum

Built in 2015, Luo Zhongli Art Museum was selected as the study site because it is one of the newest buildings on the authors' campus, the largest art museum in the city, and it hosts the institute's graduation exhibition each year. The graduation exhibition has been held for 13 years, 3 of which have been hosted at this location. This museum has an area of 13,000 m^2, displaying some 1,567 exhibition pieces across 12 exhibition halls, all of which are open to the public. During the graduate exhibition, student work in Chinese painting, calligraphy, oil painting, engraving, sculpture, craft, environmental design, and fashion design is displayed on three floors.

The museum has a unique structure, especially with respect to its halls. For example, Halls 2, 3, and 4, located on the first floor, are integrated with the second floor via a series of ramps that lead visitors through the flow of exhibitions. During the graduation exhibition, Hall 2 is reserved for a separate purpose and is not open for public. Aside from using elevators or the stairwell, Halls 3 and 4 have ramps that visitors can use to go upstairs. The highlighted areas in Figure 1 show the exhibition halls used for the graduation exhibition, which occupies three of the four floors of the museum. The remaining areas hold the museum's permanent collection. As a temporary exhibition showing a large number of pieces, our question is whether a visitor would have the chance to explore all work, or if the museum's architecture influences a visitor's decisions. Consequently, identified influences can serve as suggestions and be implemented in the design and organization of next year's graduation exhibition.

The investigation considers locations on specific floors, based on the museum's physical structure and the exhibition's organization. First, during the graduate exhibition only one entrance was open, so all visitors had to enter through the main entrance (see Figure 1) and proceed through security. From this location we observed the total number of visitors within a chosen time frame, and then identified the number in specific exhibition halls.

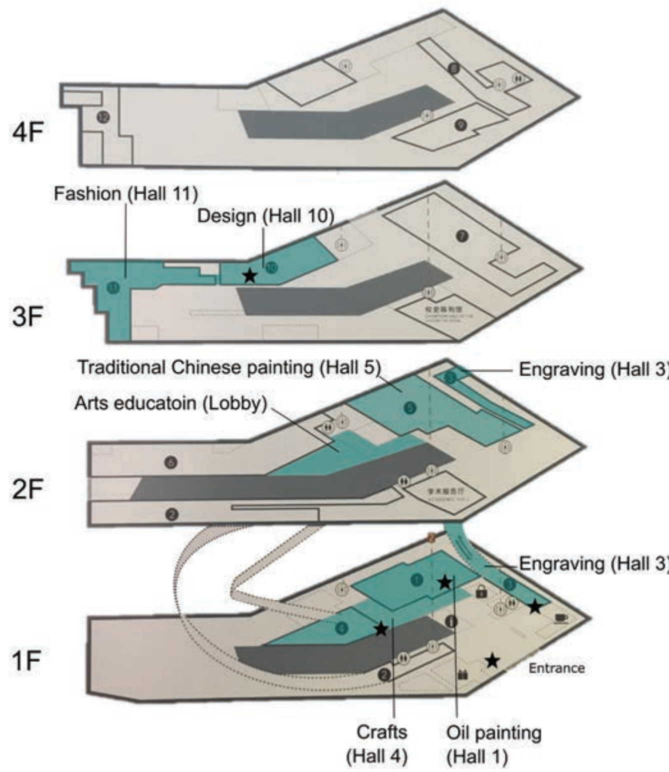

Figure 1 / Graduation exhibitions and floor plans of Luo Zhongli Art Museum (floor plan courtesy of museum). Star symbols in this figure indicate locations selected for later observations in this study.

We selected the entrances of Hall 1 (oil painting), Hall 3 (engraving), and Hall 4 (crafts) as three additional observation locations on the first floor to detect all possible visitor flows. No observations were conducted on the second floor because visitors to Halls 3 and 4 could move along a ramp to the second floor, and discerning movement decisions based solely on or influenced by architecture would be difficult. On the third floor, we chose the entrance to Hall 10 (design) as our observation spot because visitors to both Halls 10 and 11 (fashion design) can enter only through that location.

Spatial Analysis

The open-source software depthmapX was used for the spatial analysis. The software was developed as a space syntax tool for quantifying built environments and associating the quantified information with human behaviors (Penn 2003). This study employed the measures of partial isovist and visibility graph analysis (VGA) in the software to simulate the visual access of a museum visitor. It is important to note that this study does not evaluate other factors, such as differentiation of environment or layout complexity, which also contribute to an environment's legibility. As visual access is associated with spatial explorations, we did not consider using environmental differentiation, as it supports recognition of space and the spatial behavior investigated in this study is free exploration, which does not require spatial familiarity to orient oneself. For example, when a visitor walks into the museum, they can choose any of the three exhibition halls on the first floor to start. Furthermore, the museum is a large open space with a relatively uncomplex layout, so first-time museum visitors would likely not get lost. As such this provides a good space to explore the visual access resulting from the museum structure.

The research methods provide quantitative analyses of built environments based on their configuration and simulation of a person's visual access. Although these methods do not provide a fully comprehensive description of the environment, they address certain aspects of the environment that is essential to a person's spatial experiences. Beyond observing visitors, this study conducted interviews, which provided not only additional validation to the results of the spatial analysis, but also additional experiential input. This complete analysis of how environmental effects impact visitors can provide a more comprehensive understanding of the museum environment and how it can be altered to promote more exploration and an overall better experience for visitors.

Observations and Interviews

Data was collected in two phases. First, observations were conducted to determine the volume of visitors at selected locations in the museum, as a way to quantitatively assess the influence architecture has on visitors' exploration. Second, interviews were conducted with randomly selected visitors. The purpose was to provide a qualitative narrative to support the findings of earlier observations. The details of both components are described below.

All observations were carried out on Tuesday, June 5, 2018 between 2:30 and 3:00 p.m. The time frame was selected based on consultations with museum staff, who reported visitor flow was steadiest on weekdays between 2:00 and 4:00 p.m. Nine student assistants, who volunteered to participate in the study, conducted observations with the authors. In the morning of the observation day, students received training about the experimental protocol from the authors, with information about the groups, procedures, and how to record observations. The purpose of the training was to distinguish visitors from non-visitors. For example, someone may walk into an exhibition hall searching for a person or the bathroom instead of coming to the specific exhibition, and they should not be counted towards the total number of visitors. Each observation group consisted of at least two assistants who received the training; group members would take turns counting and verifying whether an individual qualified as a visitor. One hour before the actual observations, all assistants met with the authors at a random location in the museum to conduct a trial observation together, ensuring that all assistants were accurately counting visitors based on the protocol. The observations lasted 30 minutes in total, with five-minute observation periods. The visitor counts for both the six periods and overall session were analyzed.

Shortly after the observations concluded the authors went to the different exhibition halls, randomly selected visitors, and asked if they were willing to be interviewed. The authors introduced the purpose of the interview, which was to understand how a visitor would explore the museum and exhibitions, as well as to collect any suggestions that could enhance their experiences. The interview addressed the following five questions:

1. What was your first impression of the space as soon as you walked into the Museum?
2. Which was the most impressive exhibition or location for you?
3. Which exhibition hall or location was the least impressive to you?
4. What reasoning or strategies did you take to go from one exhibition to another?
5. Do you have any suggestions to enhance your experience in the museum on your next visit?

RESULTS

We first present the output from the quantitative architectural analysis, followed by descriptions of visitor observations of the museum as they relate to the spatial analysis. Data collected from visitor interviews is presented at the end of this section.

Visual Access

The isovist concept regards a person's visual access in a given location's space as restricted by its surrounding architecture, like Figure 2 represents the partial isovist at the museum entrance. Given that a partial isovist has a 120^{o} field of view, this mapping simulates the visual access a visitor has upon entering the museum, and clearly shows that a visitor can directly see the entrance of Hall 1. Entrances to other exhibition halls on this floor, however, are not visible from this location, therefore a visitor may need to investigate further and then decide whether to visit these other exhibition halls rather than freely exploring. The structure's influence on visitor decisions is discussed in the results of visitor observations.

Figure 3 shows the VGA output for the museum entrance and selected exhibition halls; the colors from dark blue to dark red represent low to high visibility, respectively. The VGA of the museum entrance shows that once visitors walk into the museum, they have a good overview of the main lobby area, but their visual attentions is likely directed toward Hall 1, which directly faces the entrance. Visitors actually have a shorter distance to the entrance of Hall 3, however the visual access to this area is less than that of the entrance to Hall 1. Around both entrances to Hall 1 the VGA shows that a person has direct visual access to the neighboring Hall 4, which allows for its discovery if this hall was not seen from the museum's entrance.

On the third-floor, visitors can only access Hall 11 through Hall 10, so it is important to investigate this dimension and the direction of visibility. VGA shows that the visibility in Hall 10 is relatively low; due to its structure, visitors

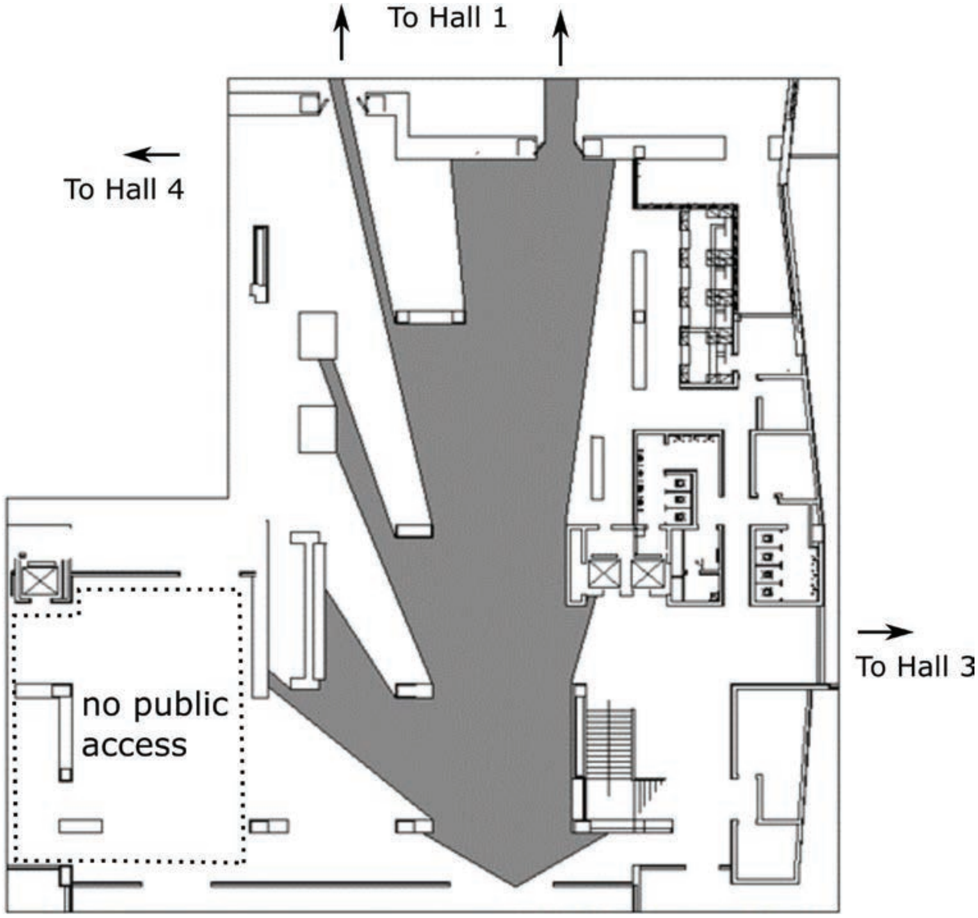

Figure 2 / Isovist simulating a visitor's visual access at the museum entrance.

are not able to see the entrance to Hall 11 until they walk to the very end of this area. It is only in this rearmost location that there is slightly higher visual access from which the entrance to Hall 11 can be seen. Overall, differences among these exhibition halls demonstrate that different architectural structures in this museum reflect various levels of visibility within the museum, which may result in different visitor exploration.

Observations

The total number of visitors was summed based on a count from every five-minute interval during the 30-minute observation window. Figure 4 shows how many visitors entered each exhibition hall. Distinguishing between visitors and non-visitors was important for ensuring an accurate count. The need for this distinction was noticeable at Hall 3, as restrooms are located near its entrance. Per the experimental design, we did not count those who were looking for the restrooms, but only those who viewed the works on display in this hall.

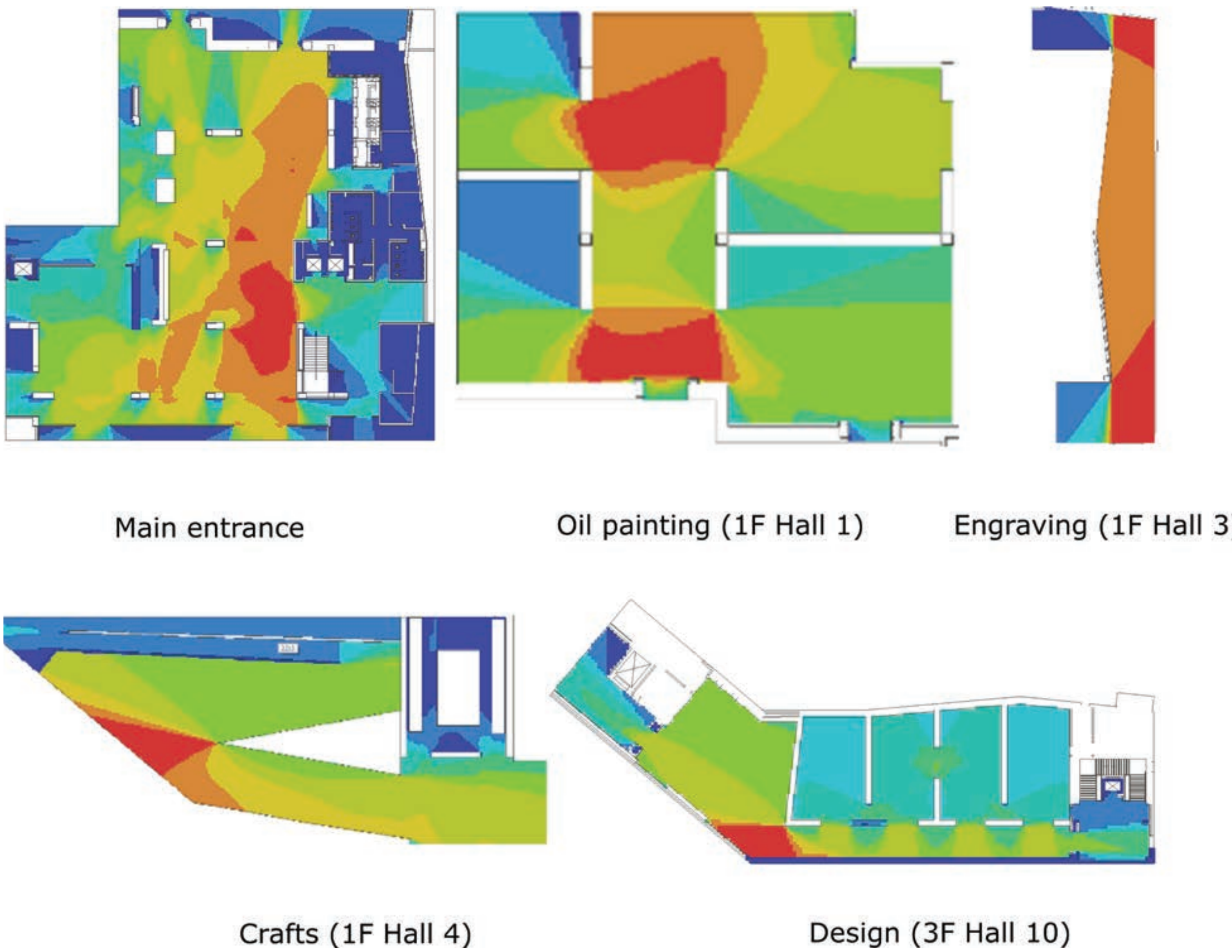

Figure 3 / VGA of observed exhibition halls showing overall visual access within each museum space.

In total, 371 visitors walked into the museum during this half-hour period, but it is important to note that some visitors may have moved very fast within the museum, visiting multiple exhibition halls, and were therefore double counted. In addition, visitors who came in before our observation window may have remained in the museum and visited some of the observed exhibition halls. Nonetheless, the volume of visitors that we counted in the exhibition halls shows the distribution of visitors within in the museum space.

Hall 4 had the highest number of visitors (249), followed by Hall 1 (184). The number of visitors to Hall 10 was the lowest (67), following behind the number of visitors to Hall 3 (123). How these numbers are associated with museum architecture is discussed after the review of the results of interviews.

Interviews

Following the observation of these exhibition halls, the authors stood at the museum's exit to seek additional information about visitors' spatial experiences randomly asking departing guests to anonymously share their experiences in the museum. Five visitors provided their thoughts in response to the authors' questions. The results here are organized by individual question. Since visitors were native

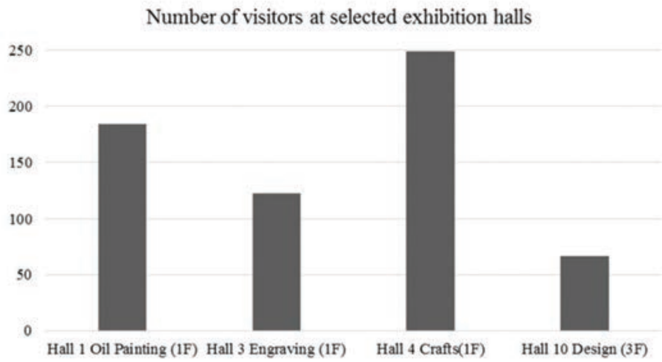

Figure 4 / Observed visitor volumes entering specific exhibition halls.

Mandarin speakers, the interviews were conducted in the visitors' native language and translated to English.

The first question asked about a visitor's initial impression of the museum as they entered the building. Many visitors mentioned that they felt the museum space was massive and they were immediately attracted to the posters highlighting the graduation exhibition. All interviewees shared that they did not know where to start, as there seemed to be many halls, but they did not find any signs or directions guiding them. In particular, three interviewees said that they picked the exhibition hall that they saw first. Interviewee 1 said, "When I just walked into the museum, I was attracted to the bold, huge poster announcing the graduation exhibition. But since I have not been in this museum before, I didn't know where to start." Interviewee 4 had a similar experience of not knowing where to start and Interviewee 2 noted that "the entire floor has been partitioned into smaller rooms with different themes. There were staircases and elevators available. But the exhibition room facing directly to the entrance was what I saw first." This opinion was closely aligned with Interviewee 3's thoughts.

The second question asked the visitors about their impression of the exhibitions. Interviewee 1 did not mention any, while Interviewee 2 stated that, "if the impression is not related to the work that I liked the most personally, I'd say that work in the hall [authors' note: Hall 1] directly facing the museum entrance and the hall right next to it in the corner [authors' note: Hall 4] as it is very spacious in this area with high ceilings and a ramp to the second floor. This was where I was most impressed." Interviewee 3 said "what impressed me the most were those works with the largest size hanging on the wall which could be viewed from multiple floors." Interviewee 4 stated that "I was mostly impressed by the oil paintings, as they are in a place that I could directly reach once I entered the museum; I just walked straight once I was in the door. Also, there were lots of visitors in this area where I spent quite some time." Based on these comments, it appears the interviewees associated their positive impressions with the architecture of the museum and the areas of direct visibility.

The third question asked which exhibit was least impactful. Two interviewees mentioned that the exhibitions of design and fashion in Halls 10 and 11, not because of the exhibitions themselves, but rather because these areas were difficult to find. For example, Interviewee 4 explicitly said that "the exhibition halls for both design and fashion were located in the wing which was the hardest to find." If I didn't remember the information from the poster that these were exhibitions of fashion and design, I would probably not have even tried to find them. It was just too hard to find." Interviewee 3 thought the general design of visitor flow was unimpressive, saying that, "There was no clear logic to view all the halls or art. I was not good at finding my way, although I didn't want to see the same work again, I found myself doing so." Interviewee 2 shared her experience in relation to the size of space, saying that "I felt least impressed by the space being separated into very small rooms and exhibitions in those small rooms didn't leave much impression on me."

The fourth question asked each interviewee regarding how they decided to explore the exhibitions and move between them. Interviewees 1 and 4 had similar strategies such as "simply follow each exhibition hall incidentally." Interviewee 2 provided more details, saying "I feel the space has some influence on my decision. If I feel a space is well connected, that will direct me to continue exploring through the space. Once I can see something in my surroundings, I'll then move on to that location." Interview 3 shared a similar strategy, that "the architecture gives me the spatial cue; I'd try to look for space that looks different so I am sure that I would not revisit a place again."

The last question asked the interviewees if anything could be improved to enhance their experience; only two of the five interviewees provided their thoughts, all of which addressed signage. For example, Interviewee 4 said that "I think all the exhibition halls were organized spatially with no big issues. But the signage or direction is incomplete." The other interviewee suggested that improvement to signage would enhance their ability to navigate the museum.

DISCUSSION

In this section, we aim to link the spatial analysis, visitor observation, and interviews, and to identify relationships among them, so they will not be discussed separately. Instead, all three aspects are organized around the observed exhibition halls and then summarized.

In Hall 1, the direct visual access from the museum's entrance clearly contributes to the volume of visitors. Interviewee comments further support this association. In Hall 3, the volume of visitors was the second lowest, despite that its distance to the entrance is the shortest. This is another piece of evidence supporting how direct visual access may contribute more to the visitors' urge to visit a particular hall when compared to spatial distance. The observations, as well as interviews, show that once a visitor has noticed Hall 1 through direct visual access and begins moving toward it, they then notice Hall 3 (a shorter distance), but this does not always outweigh the visitor's initial decision to move towards Hall 1. The entrance of Hall 3 is located next to the restrooms on the first floor. Although we have excluded non-visitors, some visitors may have noticed the exhibits in there after using the restrooms and then decided to enter.

Hall 4 received the greatest number of visitors, likely as the result of two factors. First, visitors potentially noticed this very open hall with high ceilings during their movement to Hall 1, so it might have been the logical place to go after viewing the oil paintings in Hall 1. Even if a visitor goes into Hall 1 without noticing Hall 4, they will have direct visual access to it no matter which door is chosen to exit Hall 1. As such, visitors were very likely to proceed to this space. The second factor is that visitors may choose to walk through Hall 4 to access the next floor, thereby viewing more work, rather than take the elevator or staircases without seeing anything. While we observed the highest number of visitors in this exhibition hall, it appeared that going here was not a visitor's first choice. Instead, its proximity to Hall 1 enabled it to receive a high volume of visitors seeking to explore the rest of the museum.

Hall 10 received the lowest number of visitors in our study; as compared to the other three halls, it had just half of the third most visited space. Interviewees who mentioned this hall were purposefully looking for it and those who made no mention of it likely had not visited it at all. The physical and organizational structures seem to play an important role in this instance, as Hall 10 is not located directly above other halls on the first or the second floor, but rather in the west wing on the third floor. Additionally, to separate the permanent collections from the graduation exhibition, the museum had blocked off space on the third floor. Therefore, this hall was only accessible through the back elevator and staircase.

If visitors took the ramp in Hall 4 to the second floor and intended to visit all exhibitions there, they would first go through the arts education exhibition and then traditional Chinese painting. Following that, they faced two possible options, one being to enter Hall 3 (engraving) on the second floor, whose ramp would return visitors to the first floor near the main entrance and the other would be to take the front elevator or staircase to the third floor. A section of the third floor hosted a permanent collection that did not provide access to the other side of that level, however, so visitors who went there would have likely returned to lower floors without visiting Hall 10. Only those who entered Hall 3 on the first floor and then moved on to the second floor would see Hall 10, as they would go through the traditional Chinese painting and then the arts education exhibition, where the back elevator or staircase would lead them to Hall 10. Even though visual access at its entrance is low, participants seemed to move along and explore the design and fashion exhibitions once they discover the exhibitions as the result of a singular direction of travel. A smaller portion of the visitors who entered Hall 3 might reach the exhibitions on the third floor by using an east to west exploration; the visitors counted in Hall 10 is evidence that appears to support this exploration pattern.

The visual access formed by the museum's architecture seems to play an influential role in the decision-making process around exploration. The museum selected for this study demonstrates this, as the graduation exhibition is temporary, lasting about a month before graduation, with limited signage to facilitate visitors' wayfinding. Only one poster at the entrance introduced the themes of the exhibitions, but it did not provide information of the corresponding locations. Similarly, the maps at each elevator indicated the exhibition halls by their number, but no indication of particular collections was made. Therefore, the absence of signage likely contributed to incomplete explorations. For instance, the observed number of visitors shows that direct visual access, not proximity, has a greater impact. Only a limited number of observed visitors entered a closer exhibition hall initially, then moved to the second floor, explored those exhibitions in one direction, and upon reaching the back elevator or staircase visited the third-floor exhibitions.

Visual access in the museum and its architecture for transiting visitors to the next floor generates an intuitive and exploratory flow for visitors, though only on the first two floors. Guiding visitors to the exhibition halls on the third floor remains a challenge, so identifying navigation enhancements for the third floor is worth discussing. For example, inexpensive or inobtrusive architectural changes are possible. Some additional information or temporary signs may contribute to a number of visitors on the third floor and to do that, the poster listing relevant exhibitions can be expanded to show not only the corresponding hall numbers and collections, but also indicate the floor. Furthermore, temporary maps positioned near the elevator could be easily used to show the names of collections and their corresponding locations, rather than just exhibition hall numbers as those are used only by museum management. This change would be helpful for visitors seeking a suggested exploratory route rather than free exploration. Additionally, an integrated exploration path that a visitor could make use to enhance their spatial experiences in this museum should be considered.

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Analysis of Signage Using Eye-Tracking Technology

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Abstract /

Signs, in all their forms and manifestations, provide visual communication for wayfinding, commerce, and public dialogue and expression. Yet, how effectively a sign communicates and ultimately elicits a desired reaction begins with how well it attracts the visual attention of prospective viewers. This is especially the case for complex visual environments, both outside and inside of buildings. This paper presents the results of an exploratory research design to assess the use of eye-tracking (ET) technology to explore how placement and context affect the capture of visual attention. Specifically, this research explores the use of ET hardware and software in real-world contexts to analyze how visual attention is impacted by location and proximity to geometric edges, as well as elements of contrast, intensity against context, and facial features. Researchers also used data visualization and interpretation tools in augmented reality environments to anticipate human responses to alternative placement and design. Results show that ET methods, supported by the screen-based and wearable eye-tracking technologies, can provide results that are consistent with previous research of signage performance using static images in terms of cognitive load and legibility, and ET technologies offer an advanced dynamic tool for the design and placement of signage.

Keywords /

eye-tracking; signage; context

SIGNAGE AS COMMUNICATION

Signs, whether freestanding, building-mounted or interior, exist in a variety of forms and manifestations. They may include a combination of letters, words, graphics, and symbols composed in a variety of colors, materials, textures, and lighting. Whatever their composition, signs can provide essential visual communication for wayfinding, commerce, and public dialogue and expression. Those interested in how the design, placement, and potential regulation of signs may impact their effectiveness will appreciate that signs are viewed in the context of their visual environment, with their impact on human behavior reflecting a complex array of experiential, psychological, and physiological factors.

To have their intended impact, signs need to capture the subconscious visual attention of viewers. Vision science has established that in humans this pre-attentive viewing or visual attention is innately drawn to visual elements that contains lines and edges, red/green and blue/yellow contrasts, intensity against context, and facial features within the visual environment; these visual elements are considered triggers of the conscious viewing required for response (Moore, 2011). Through the perception of form, spatial configuration, light, and material, the contextual built and natural environments influence how viewers experience signage. As with other elements of the built environment, signage is best understood to be experienced in its full context and has its impact through a combination of sensation and perception, learning and memory, decision making, emotion and effect, and movement (Eberhard, 2009). Signage design, to be effective, must appreciate "the complex, intricate, overlapping functioning of our sensorimotor systems, by deepening our understanding of how our nervous system binds us to our world, and showing how that world doubles back to shape us"(Robinson, 2015; 366).

Given the significant contextual and cognitive issues related to the design and placement of signage, it is not surprising that research has found that not all signs, or even identical signs in different contexts, are equally successful in capturing the visual attention of potential viewers (Auffrey and Hildebrandt, 2017). How well a sign communicates its message reflects how design and placement accommodate and respond to the contexts of its surrounding built and natural environments. As such, tools and methods are needed that can inform design and regulation decisions by objectively assessing how well signs capture the attention of their intended viewers. This is especially true in complex visual environments, both outside and inside of buildings.

Capturing visual attention is important because it is a prerequisite for the conscious viewing required to achieve the response intended by sign owners. As such, how well a sign attracts visual attention is an important measure of its potential effectiveness in eliciting desired behavior. Yet, a shortcoming of signage design and regulation research is the limited use of objective measures of visual attention that includes the surrounding real-world visual context of signs (SRF, 2019; Garvey and Crawford, 2014). Further, signage research has been frequently directed at static, single-perspective images rather than the multi-viewer dynamic video analytics now available with wearable eye-tracking (ET) technology (Auffrey and Hildebrandt, 2017).

Consequently, the research presented here uses ET technologies to better understand the impact of signage design and regulation on the capture of visual attention across varying contexts. Of special interest is the use of ET methods and analytics from both screen-based and wearable ET technologies, which provide objective, multi-user performance measures in complex, real-world visual contexts.

RESEARCH DESIGN

To better understand how ET technology can be used to produce sign effectiveness metrics and therefore inform signage design and regulation, an exploratory research design was employed where both screen-based and wearable ET hardware and analytic software were used to collect and summarize data for two groups of research participants subjected to two discreet visual environments (see Figure 1). Exploratory research is useful in the development and refinement of research techniques, especially when new technology allows measurement and assessment that was not previously possible (Stebbins, 2001). In this regard, exploratory research methods can be especially useful to compare the new technology with earlier approaches and lay the groundwork that will establish the uses and limitations of new technology in specific applications.

As such, this research seeks to establish the uses and limitations of both screen-based and wearable ET

Figure 1 / Screen-based exe-tracking (L); Wearable eye-tracking (R).

hardware and software for signage research. ET studies are intended to capture conscious viewing and to solicit feedback from subjects about what they are looking at and thinking, so ET technology was applied to visually-complex real-world environments, with the intent to assess how it measures visual attention. These patterns would then be compared to established visual science factors. The specific exploratory approach used here uses descriptive, qualitative, and quantitative assessments of screen-based and wearable ET analytics for specified "areas of interest" (AOI) within photos and video capture. Heatmaps and gaze plots also were assessed. The research was conducted over two phases.

Phase 1: Screen-Based Eye-Tracking

The first phase used screen-based ET to document the specific visual elements which drew the visual attention of research participants. The specific exploratory approach uses descriptive, qualitative, and quantitative assessments of four ET analytics (mean time to first fixation, mean total fixation duration, mean fixation count, and mean total visit duration) for specific AOIs within four photos. Two of these images were from US college campus scenes that include buildings and walkways, a third was a street perspective of an urban art museum building in a US city, and the fourth was a street scene of commercial buildings in a Chinese city. A total of 45 college student volunteers participated; all were familiar with the US-based images and none were familiar with the Chinese scene.

Research participants were asked to observe a sequence of photographs while seated directly in front of a 24-inch high-resolution video display. The display was equipped with a Tobii Pro screen-based ET device with illuminators and a data processing unit. The processing unit collects data for individual participants and outputs aggregated metrics for image detection, 3D eye modeling and gaze mapping.

To begin, each subject went through the standard ET calibration and verification procedure, as specified by Tobii. The photographs were each displayed for three seconds, reflecting a predetermined "Time of Interest" (TOI). TOIs are defined interval of analysis used in ET research that allow for the organization of data according to time periods where meaningful behaviors and events take place (Tobii, 2019). In this case, three seconds represent the period prior to conscious viewing, where subjects' visual attention is directed to areas based on innate human response rather than conscious viewing.

In addition, AOIs were specified in each of the images, selected to assess how the measured eye movements were drawn to the visual elements considered triggers of the conscious viewing required for response. These include lines and edges, red/green and blue/yellow contrasts, intensity against context, and facial features within the visual environment. Based on the specific interests of the researchers, AOI boundaries were digitally selected; eye movement metrics would be calculated and exported for those elements. These metrics provide quantitative measures of how each AOI attracted visual attention across the participants. For this exploratory research, four metrics were measured for the selected AOIs:

1. Time to the first fixation, defined as the elapsed time between a start event until the first fixation occurs in each AOI,
2. Number of fixations, defined as the number of fixations that occur in each AOI,
3. Total fixation count for each AOI, and
4. Duration of fixation, defined as the elapsed time between the first gaze point and the last gaze point in the sequence of gaze points that makes up the fixation.

All four metrics are important indicators of how specific visual elements attract attention and ultimately trigger the conscious viewing required for response. As such, they can potentially inform decisions about signage design and regulation.

In addition to the fixation data for each of the AOIs, fixation heat maps were generated for the entire visual field and were used to identify those areas with the most focus of visual attention across multiple participants. The heat maps are a particularly useful tool for visualizing and understanding where fixations are most concentrated, comparing fixations across the different AOIs, and identifying those visual elements apart from the selected AOIs attracting visual attention.

Phase 2: Wearable Eye-Tracking

In the second phase, 22 student volunteers used Tobii Pro glasses, a wearable ET device, while walking in a defined space with observable signage. This device includes illuminators, a camera, and data collection and processing units for image detection, 3-D eye modeling, and gaze mapping algorithms. Like the screen-based ET, the images captured by the wearable ET are used to identify glints on the cornea and pupil. This information, together with a 3-D eye model, is then used to estimate the gaze vector and point for each participant (Tobii, 2019). In contrast to screen-based ET, wearable ET allows binocular coverage, with a full field of view and head tilt capabilities. Also, it avoids potential experimental bias resulting from a screen's size or pixel dimensions.

After a standard ET calibration and verification procedure, participants were instructed to walk in a defined space while wearing the glasses. In this case, the TOI was set at 60 seconds, recording a defined beginning and end of the visual occurrences over that period. Given the longer TOI period, the data collected reflects both pre-conscious (first three seconds) and conscious viewing.

Fixation and saccade data for the wearable ET device was exported for each participant. Fixations are the periods where the eyes are relatively still, holding the central foveal vision in place so that the visual system can take in detailed information about the focus of visual attention. Saccades are eye movements which move the fovea rapidly from one point to another. Based on the fixation filter and threshold, the fixation-saccade-fixation sequence can be computed in the Tobii analytical software. For example, if two gaze points are within a pre-defined minimum distance from each other or possess a speed below a defined threshold, they will be allocated to the same fixation (Tobii, 2019).

As with the screen-based ET, boundaries for AOIs were digitally selected so eye movement metrics would be calculated and exported for specific elements. For this exploratory research, three metrics were measured for the selected AOIs:

1. Time to the first fixation, defined as the elapsed time between a start event until the first fixation occurs in each AOI,
2. Number of fixations, defined as the number of fixations that occur in each AOI, and
3. Duration of fixation, defined as the elapsed time between the first gaze point and the last gaze point in the sequence of gaze points that makes up the fixation.

As discussed previously, these metrics are important indicators of how specific visual elements attract attention and trigger conscious viewing, thereby informing signage design and regulation decisions.

In addition to the AOIs, fixation data can be visualized as gaze plots and heat maps for the entire visual field. Gaze plots show the location, order, and time spent looking at specific locations in the visual field and heat maps are used to identify those areas with the most focus of visual attention across multiple participants. Both were generated identifying the visual pathways and fixations over the course of the TOIs for all 22 participants. A panoramic (360-degree) view is used for generating the gaze plots, heat maps, and AOIs.

FINDINGS

This research is part of an ongoing inquiry into the unique advantages of screen-based and wearable ET for studying signage within its context. The results reinforce and add to prior research about how the presence and placement of specific visual elements in signage and wayfinding design is important for the capture of both pre-cognitive visual attention and conscious viewing. As part of this exploratory research, the focus of this paper has been on four visual elements as part of signage design and placement. This includes proximity to edges and lines, red/green and blue/yellow contrast, intensity, and saturation of color, and use of facial features.

Proximity to Edges

The edge of an image can be defined as a boundary line reflecting changes in a pattern; edges define shape and necessarily attract visual attention. The results of this research show higher fixation metrics where linear visual elements (edges or lines) appear near a background or nearby objects, such as with the wall edges or roof profiles against the sky. Fixation heat maps show higher levels of visual attention on signage along the edges of building façades. Further, aligning signage with edges potentially serves to facilitate wayfinding by directing a circulation flow based on visual cues.

Results from the screen-based ET analysis of an image with college campus buildings and walkway shows participants' visual attention was better captured by signage along the edge of a building façade rather than the larger, homogeneous façade system itself (see Figure 2). The results suggest that the alignment of signage with the façade edge may better serve wayfinding needs (in this case, building identification) and therefore facilitate pedestrian movement.

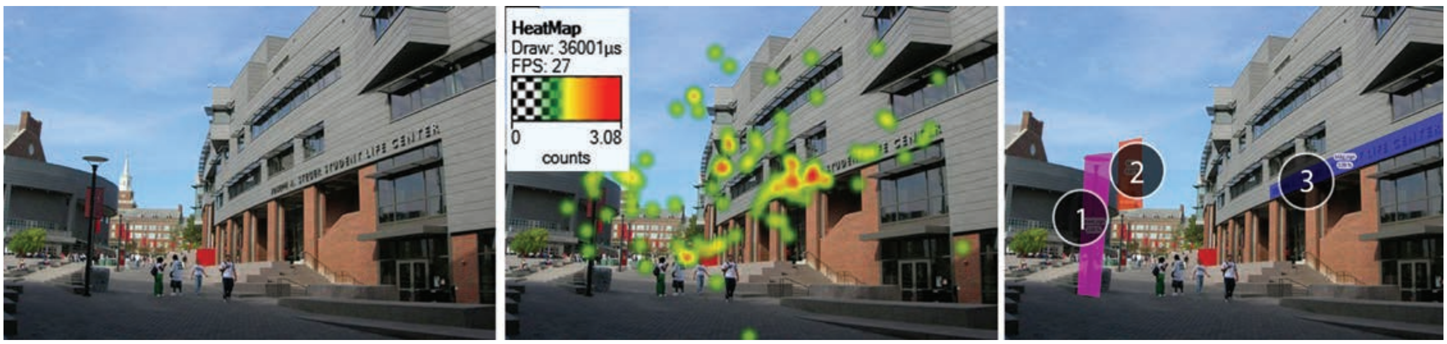

Figure 2 / College Campus Buildings and Walkway: Image (L), Heatmap (M), and AOIs (R).

For this image three AOIs were selected: the vertical banner hanging on the light pole, a building tower in the distance (a strong edge against the sky backdrop), and the block letter signage along the edge on the building façade. The ET fixation metrics for the AOIs show participants' attentions were most quickly focused on the block letter signage on the building (mean time to first fixation = 1.04 sec.) compared with the other AOIs (see Table 1). The block letter AOI also has the longest total duration (0.42 sec.), the largest fixation count (2.14), and the largest mean number of visits (0.46). These results suggest that signage placement near an edge increases its visual attention as a visual feature.

Table 1 / Area of Interest Eye-Tracking Metrics for Figure 2.

Areas of Interest	Time to First Fixation	Total Fixation Duration	Fixation Count	Total Visit Duration
1. Banner on light pole	1.5	0.29	2	0.31
2. Tower on distant building	1.33	0.38	1.33	0.4
3. Block letter signage on building façade	1.04	0.42	2.14	0.46

The wearable ET analysis provided additional results that could not be provided by the screen-based ET. The results suggest the importance of the placement of the signage relative to the expected viewing angle of potential viewers. The typical human vertical binocular coverage is approximately 50 degrees above the line of sight, and while wearable glasses allowed participants to tilt head freely, very few gaze points are recognized beyond this (see Figures 3 and 4).

Figure 3 / Art gallery panoramic image with "exit" sign indicated (above); Art gallery panoramic image with heat maps for eye fixations, N=22 (below).

Figure 4 / Interior of campus building where "exit" sign is in a pattern-free wall, within the vertical binocular coverage, and reinforced by vanishing point.

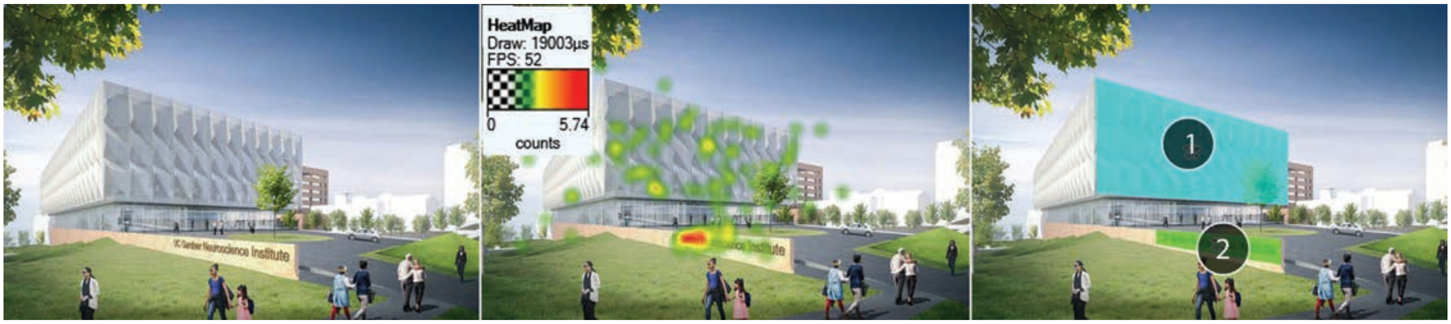

Figure 5 / Rendering of proposed college research center: Image (L), Heatmap (M), and AOIs (R).

Red/Green and Blue/Yellow Contrast

One of the images included in the screen-based ET analysis was used to explore the impact of red/green and blue/yellow contrast on visual attention. The image, a graphic rendering for a proposed college research building, included a low monument sign with color contrast and a large building façade composed of neutral gray material. Both the sign and façade were designated as AOIs for the analysis. Although the signage area represents only 1.5 percent of the image, compared to 11.7 percent for the building façade, the higher contrast of the sign elicited considerably more visual attention. The heat map shows that the number of fixations on the sign is higher than the building facade (see Figure 5).

The AOI metrics show higher values for the sign in all four categories: time to first fixation, total fixation duration, fixation count, and visit duration (see Table 2). Given that both AOIs contain substantial edge/line features, the higher contrast of the sign suggests an explanation for higher levels of visual attention on the signage.

Table 2 / Area of Interest Eye-Tracking Metrics for Figure 3.

Areas of Interest	Time to First Fixation	Total Fixation Duration	Fixation Count	Total Visit Duration
1. Building façade	0.72	0.93	4.17	1.04
2. Monument sign along wall	0.19	1.21	6	1.51

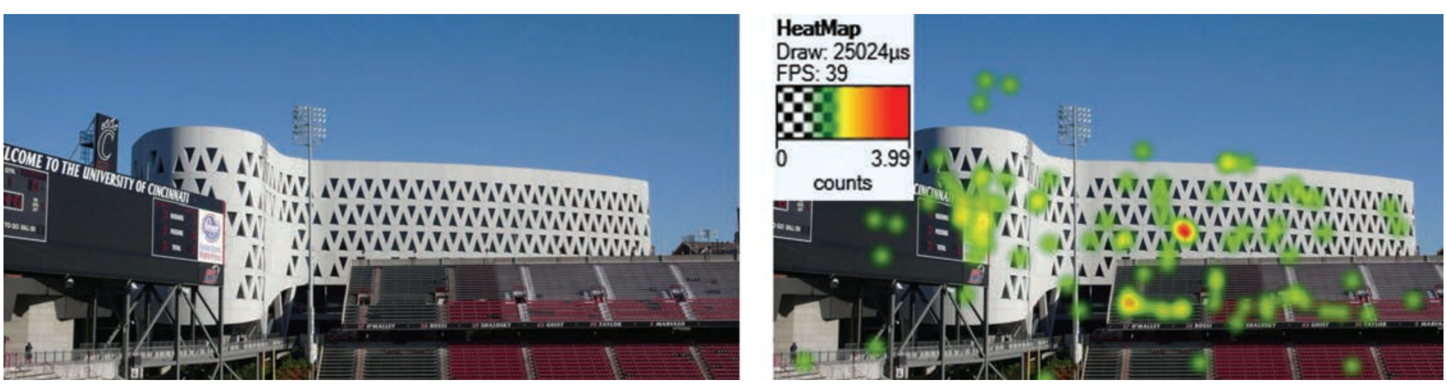

Figure 6 / Sign on scoreboard near high-contrast building façade: Image (L), Heatmap (R).

In comparison, an image with a low-contrast sign and a high-contrast building façade resulted in a different outcome (see Figure 6). The heat maps show how sharp triangular patterns and high black-white contrast on the building façade attracted more attention than the scoreboard mounted sign.

Intensity/saturation of color in context

The eye-tracking analysis was used to assess the impact of intensity and color saturation on visual attention. The pink lettering against a black background on the third level of an urban art museum building provided intensity and saturation of color that attracted higher levels of visual attention than the other elements of the building façade. The corner placement provides an edge to attract visual attention and allows visibility from two directions (see Figure 7). The heat map shows that the street sign and commercial lettering on the delivery truck received less visual attention.

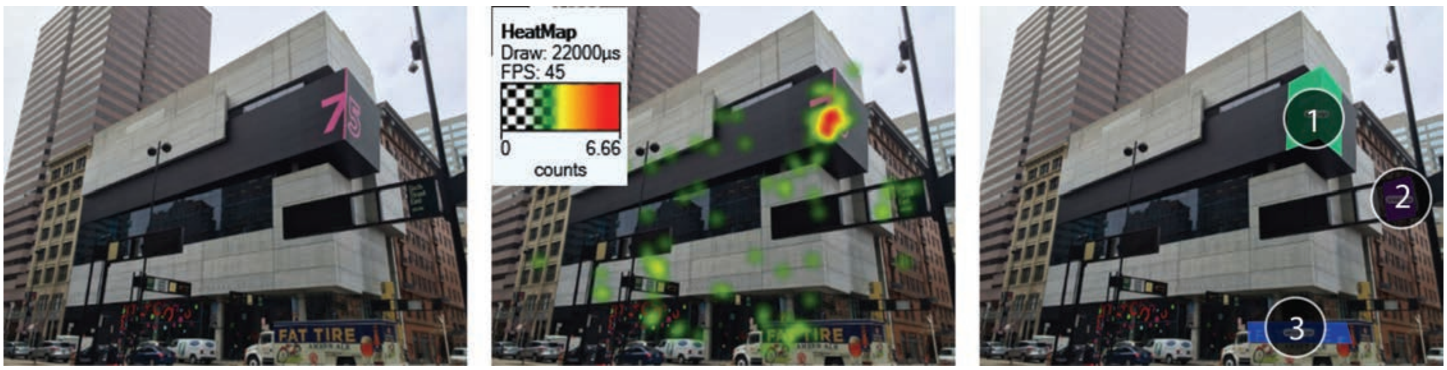

Figure 7 / Urban Art Museum Building: Image (L), Heatmap (M), and AOIs (R).

Table 3 / Area of Interest Eye-Tracking Metrics for Figure 6.

Areas of Interest	Time to First Fixation	Total Fixation Duration	Fixation Count	Total Visit Duration
1. Art museum building lettering	0.57	0.97	3.1	1.06
2. Street sign	1.65	0.65	1.5	0.66
3. Delivery vehicle lettering	2.39	0.46	2	0.5

Facial images in context

Human brains devote more areas to facial recognition than recognizing any other visual object (Sussman and Hollander, 2015). This reflects how our brains are hardwired to focus visual attention on other humans within sight. This priority is described by Chalup et al. (2010) as "face-a-tecture," where the subconscious will perceive facial features as part of the structural design. This concept was explored using the screen-based ET to analyze an image with signage using a facial feature.

In a street scene of commercial buildings in a Chinese city, signs are installed on building façades and storefronts (see Figure 8). The scene contains strong

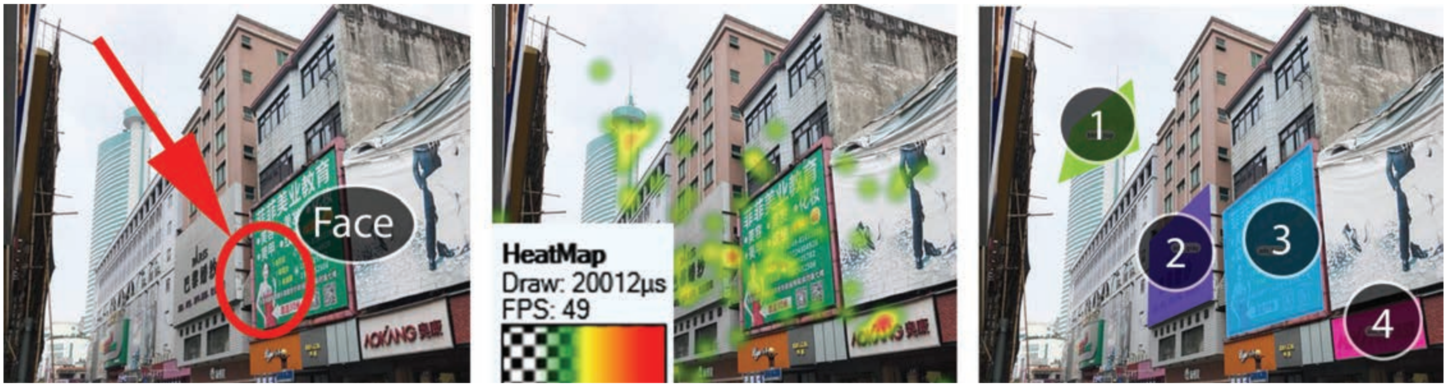

Figure 8 / Street scene of commercial buildings in China: Image (L), Heatmap (M), and AOIs (R).

Table 4 / Area of Interest Eye-Tracking Metrics for Figure 7.

Areas of Interest	Time to First Fixation	Total Fixation Duration	Fixation Count	Total Visit Duration
1. Distant building tower	1.43	0.34	1.4	0.38
2. Store name signage (far)	1.03	0.63	2	0.64
3. Signage with a human face	0.39	0.46	2.88	0.56
4. Store name signage (near)	1.34	0.43	1.75	0.45

edge features reflecting a vertical structure against the sky and a face image on signage (AOI #3). The screen-based ET metrics for the picture show that the signage with a human face received the first fixation and highest fixation count (see Table 4), however its total fixation duration is lower than other signs. Interestingly, the vertical tower also received visual attention, but with a longer "time to the first fixation," suggesting the signage with facial features may have been a higher priority than the tower.

Figure 9 / Interior of building with a hanging poster containing human face, panoramic view: Image (above); heat maps (below).

The importance of facial features to attract visual attention also was explored using the wearable ET analysis. The resulting panoramic image and heat map of the interior of a college building show the relative visual attention on a hanging poster of a seated person whose face is clearly exposed (see Figure 9).

While the face on the poster is attracting eye fixations, the total number of fixations are fewer than the fixations on the seated persons below the poster. As with previous findings, it appears that visual attention is reduced if the facial features are outside the viewers' vertical binocular coverage. Although the wearable glasses allow people to tilt head freely, relatively fewer eye fixations are recorded outside the vertical binocular coverage.

CONCLUSIONS AND IMPLICATIONS FOR FUTURE SIGNAGE RESEARCH AND PRACTICE

The screen-based and wearable ET technologies are useful tools for assessing visual attention in complex environments. While the implications for more efficiently promoting commerce and routine wayfinding are important, even more essential are the lessons for emergency egress from crowded buildings. The results of this exploratory work reveal both opportunities and limitations of ET research tools regarding visual communication challenges.

Clearly, ET technologies have demonstrated their usefulness to provide information that can be used to refine concepts throughout the design process and provide quantitative measures of the performance of signage design and placement given its context related to architectural forms, edges, contrasts, intensity, and facial patterns. The examples provided from this research have shown how quickly specific elements of signage and its surrounding visual context can attract viewers' attention and for how long that is sustained. The practical applications that emerge from this knowledge is useful, but more precise design clues are needed for complex, high-stakes environments. ET gaze plots, heat maps, and fixation metrics provide results that

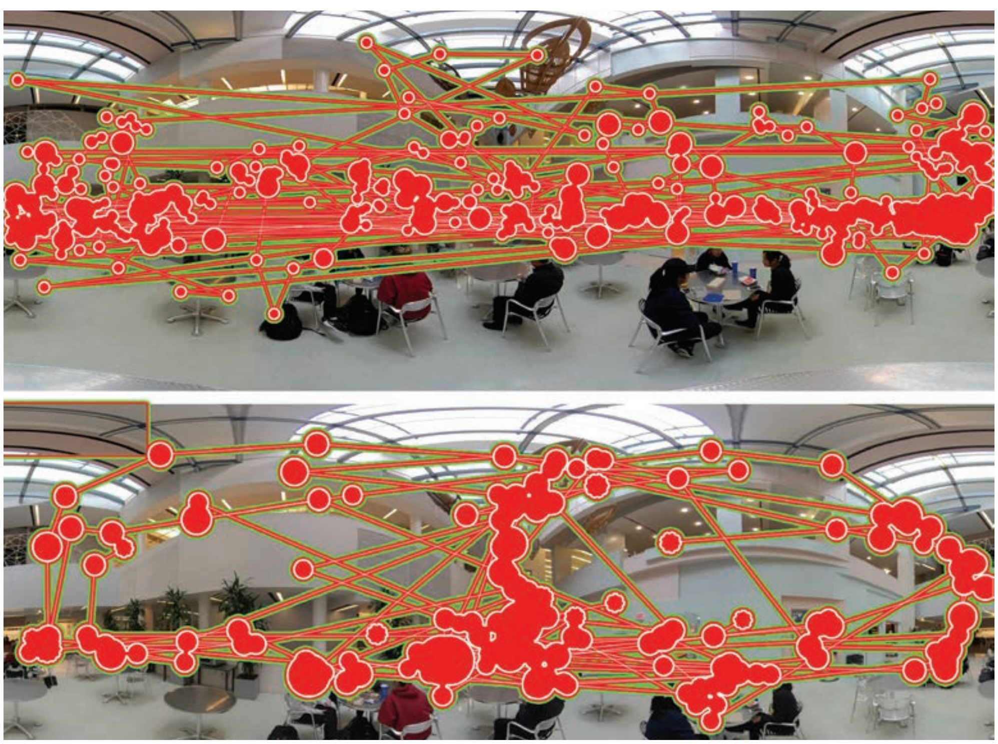

Figure 10 / Interior of building, panoramic view: Gaze data from wearable ET (top); Gaze data from screen-based ET (bottom).

require and deserve further study to better uncover adaptive responses and optimize attention in unique environments. In short, the quantifiable ET analytics have the potential to improve visual attention by informing sign design as related to its particular context.

Given its potential and growing use as a research tool, the limitation of screen-based ET, that it does not consider the human binocular field of vision, must be recognized. Wearable ET data shows few head tilts and limited gaze points outside the vertical binocular coverage, even though ET research participants can tilt their heads freely. As a result, most of the gaze points have been concentrated at a middle height within the captured images, however, with screen-based ET there are more gaze points towards the upper part of the image because there is no consideration of head tilt (see Figure 10). The assumption is that the wearable ET results better reflect how real-world viewers survey a visual scene, though further research is needed to confirm this.

In conclusion, the five basic visual elements that attract visual attention in humans should be critical drivers for those concerned about visual communication. Further research using research tools from other fields, such as pupil dilation response, electroencephalography (EEG), and galvanic skin conductance, as adjuncts to ET analysis may provide additional insight and new perspectives for signage design. Such a combination of tools may better reveal how specific elements provoke emotional responses, whether calming or stressing. The benefits of these additional sensory data as interpretable metrics may open new opportunities for signage and wayfinding research that takes advantage of findings in neuroscience.

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