An Introduction
Jourdan, D.
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The second issue of the Interdisciplinary Journal of Signage and Wayfinding is dedicated to the topic of visibility. As simply put by the Texas Transportation Institute:

> Seeing the road and everything around it while driving is not a preferred option, rather it is an essential component of safe driving. Driving is a visual activity, and as we make our way down a road, we all look at a wide range of visual inputs—the roadway, the surrounding terrain, other vehicles, roadside buildings and advertisements and traffic control devices such as signs, markings, and signals—to help us get where we are going. How we distinguish those visual inputs and maneuver the vehicle safely varies from person to person and can depend on quite a number of random, uncontrollable things—the weather, time of day, driver age, health and experience, as well as unexpected distractions inside or outside the vehicle—all can have an effect.

https://tti.tamu.edu/group/visibility/, last visited 6/12/17. As businesses know, their businesses must be visible to be viable. Clear signage enhances their visibility in the marketplace.

Regardless of sign type or intended audience, being able to see and read the message on a sign is critical. In this issue of the Interdisciplinary Journal of Signage and Wayfinding, Bullough explores the literature on visibility as it relates to the conspicuity and legibility of signage. This article provides contexts for what we know about the typographic and symbolic characteristics of signs, as well as the environments in which they are placed. Pedestrians rely on signs to help them navigate exterior and interior environments. Apardian and Alum demonstrate the importance of different high-visibility pedestrian warning signs at midblock crossings for pedestrian safety. Symonds explores the significance of clear wayfinding strategies inside airports while Ward and his students provides an analysis of the critical wayfinding elements on college campuses.

Visibility is also critical for motorists as they traverse US roadways. Auffrey and Hilderbrant provide an accounting of the lost opportunities of those businesses whose signs cannot be viewed by passersby. Utilizing 3M's Visual Analysis Software, the researchers demonstrate the average probability that a sign is being viewed by motorists and make recommendations for improving visibility.

FACTORS AFFECTING SIGN VISIBILITY, CONSPICUITY AND LEGIBILITY: REVIEW AND ANNOTATED BIBLIOGRAPHY

John D. Bullough, Ph.D.
Lighting Research Center, Rensselaer Polytechnic Institute
21 Union Street, Troy, NY 12180
Email: bulloj@rpi.edu, Web: www.lrc.rpi.edu

ABSTRACT

This paper summarizes published research studies, technical reports and codes and standards related to the visibility (i.e., conspicuity and legibility) of signage. In the summary that follows, publications are grouped and discussed according to several different topics. First, the typographic and symbolic characteristics of signs and the information they carry are described (e.g., letter size, font selection, etc.); second, photometric, colorimetric and temporal properties of signs as they affect visibility; finally, environmental considerations (e.g., daytime versus nighttime viewing, whether a sign is located in a rural or urban area, etc.) as they influence sign design are reviewed. Annotated summaries of each publication in the literature review are included at the end of this paper.

1. INTRODUCTION

Signs form a critical part of the visual outdoor environment. They provide key wayfinding cues to drivers and pedestrians about the locations of businesses and other places of commercial and government activity, and they serve as landmarks for navigating through many urban, suburban and even rural areas. Of course, many signs also serve the purpose of advertising for, and increasing awareness about, the businesses that install and use them. Undoubtedly it is the intent of every sign installation to be both noticeable and legible. Noticeability, or conspicuity, is the property of standing out from one's environment or surroundings. Legibility is the property of being able to be read and understood clearly. Factors that make a sign noticeable are not always the same that make them legible under the same conditions. For example, temporal modulation such as flashing is often employed in applications of signal lights to make them more conspicuous (Crawford, 1962), but flashing often renders text more difficult to read (Milburn and Mertens, 1997). Similarly, increasing the luminance or brightness of a sign would generally be expected to increase its noticeability (Schieber and Goodspeed, 1997) but excessive brightness can lead to irradiation of the characters and symbols on the sign (Cornog and Rose, 1967), reducing their legibility.

A challenge to reviewing the characteristics of signs as they relate to aspects such as conspicuity or legibility is that these factors are, in turn, dependent upon the specific conditions that are present when a particular sign is being viewed by a particular individual. Different signs have different purposes: highway signs may provide regulatory information (e.g., stop, speed limit) or navigational cues (e.g., street signs). Others may serve as landmarks for commercial businesses, or simply reinforce a brand identity. Obviously, requirements for these purposes differ. Further, an individual observer's age, mood, and state of distraction can render a nominally adequate sign virtually invisible, whereas in many experimental studies, observers are sober, alert and generally compliant to experimenter instructions. Many of the studies reviewed in this paper used a specific context when investigating sign characteristics. The present review focuses on the visual acquisition of text as it might be viewed by a vehicle driver with reasonably good visual faculties and alertness. Application to individuals impaired by sensory limitations, distraction or other factors, is necessarily imperfect.

2. TYPOGRAPHIC AND SYMBOLIC CHARACTERISTICS

2.1. Conspicuity

Perhaps because signs, by their nature, are supposed to attract attention of drivers and pedestrians, conspicuity (the ability to detect the sign) is less studied than legibility (the ability to read and process the information on the sign). Nonetheless, a few typographic and symbolic factors have been demonstrated to affect conspicuity of signs.

One of the most obvious may be the size of the sign itself. The U.S. Small Business Association (U.S. SBA, 2003) provides guidelines for the size of signs based on the speed of approaching traffic; for example, larger signs are recommended for posted speeds of 55 mph than for 25 mph. Bertucci (2003) describes a calculation method for determine the necessary size of an on-premise sign based not only on a vehicle's traveling speed but also on the type of reaction needed (e.g., whether a driver will need to make a driving maneuver based on the content of the sign).

Forbes (1972) devised a model for estimating the distance at which a highway sign, such as a guide sign, can be detected, and one of the factors incorporated into the model is the contrast between the letters on the sign and the rest of the sign itself. Higher contrast is predicted to ease detection of the sign at a greater distance, making it more conspicuous.

Finally, adding a border around the sign itself will often enhance the conspicuity of the sign. Possibly because the exact contrast between a sign and its background cannot always be known, when a sign is outlined by a border it may be easier to pick out as a (usually) rectangular object among other visual stimuli along the road, and FHWA (2004) requires this for almost all highway signs. Gates et al. (2004) found in real-world installations that a red reflectorized border around highway speed limit signs increased conformity with the sign's posted speed limit, suggesting that the border may have helped make the sign more difficult to ignore.

2.2. Legibility

Many more studies of the legibility of signs and factors that influence the reader's ability to process the information on the sign have been conducted. Reading and understanding a sign and being able to respond to it (by executing a turning maneuver, for example) takes time, during which the sign must be legible. That time is estimated by Kuhn et al. (1997) to be about 5.5 seconds; the Town of Bermuda Run (2013) uses a processing time of 8 s in its design guidelines for signs. Related to processing time, the amount of information that should be included on a sign has been addressed in research as well as municipal standards. While Hawkins and Rose (2005) found that there are few negative consequences of combining dual logos into a single logo space on blue service signs used along highway exits, graphical information such as logos will certainly differ from textual information on a sign, and accordingly there are cautions against packing too much information on a sign (City of Davis, 2010). The City of Saratoga Springs (2012) suggests a maximum of 8 words per sign.

The amount of information on a sign can also be related to the size of the sign itself. Several municipal codes limit the percentage of a sign's area that can be covered by letters or symbols on the basis that an overly crowded sign will be less legible. The maximum amount of a sign's area that it permitted to contain characters ranges from 40% (Town of Huntersville, 2009) up to 75% (City of West Hollywood, 2002; City of Davis, 2010; City of Bellflower, 2016).

Related to the study by Hawkins and Rose (2005), evidence suggests that legibility can also be improved by using graphical symbols rather than alphanumeric characters, at least for highway signs (Kuhn et al., 1997). This is also reflected in municipal code language presumably addressing on-premise signs (City of West Hollywood, 2002). It may be worth noting, however, that the use of symbols can lead to longer and more frequent visual fixations by drivers, which is not always a desirable response (Pankok et al., 2015). Additionally, text has a natural visual scan pattern (e.g., left to right, from top to bottom) whereas the presence of symbols on highway signs may result in less consistent and less efficient visual scanning (Pankok et al., 2015). When symbols are used, some literature on display effectiveness suggests that they should be simple (Duncanson, 1994), since not all symbols are equally legible when displayed on a highway sign (Schnell et al., 2004). Nonetheless, in addition to aiding in legibility, symbols can reinforce desired behaviors in drivers (e.g., yielding to pedestrians in crosswalks) when they accompany other types of visual information such as warning beacons (Van Houten et al., 1998), and are powerful elements of communication.

For signs using alphanumeric characters, the impacts of typeface or font on legibility have been investigated by many researchers. Appropriate font use can result in smaller footprints of the text on a sign while simultaneously improving legibility, as found in a study of roadside signs used near national parks (Garvey et al., 2004). On highway signs, an alternative font, Clearview, was found in several experimental studies (Garvey et al., 1997, 2016; Hawkins et al., 1999) to result in greater legibility distances. Studies using other fonts led to several empirical conclusions: Bank Gothic Light, Dutch Regular and Dutch Bold fonts were found to result in superior acuity than Commercial Script Regular (Garvey et al., 2001); the latter is a script font similar to cursive handwriting. The Futura font was found to be as legible as standard highway fonts for wayfinding signs in another study (Garvey, 2007). Municipalities tend to discourage the use of script-type fonts that emulate handwriting for on-premise signs because of their reduced legibility (Town of Bermuda Run, 2013; City of Bellflower, 2016), although municipal code language tends to be qualitative and not specific regarding specific type fonts that may or may not be used.

One of the distinguishing features among different fonts is the presence or not of serifs, and a few studies have evaluated the extent to which serifs impact legibility. The bulk of the evidence (Carter et al., 1985; Kuhn et al., 1998) suggests that there are no legibility differences between serif and non-serif fonts. In contrast, Tinker (1966) summarizes research stating that serifs aid in legibility. Arditi and Cho (2005) found no differences at suprathreshold visibility levels, but near the acuity limit, found fonts with serifs to be beneficial. Only one example in which non-serif fonts outperformed serif fonts was identified (Yager et al., 1998), but this effect only occurred at low light levels; at higher light levels, serifs made no difference on legibility. With the exception of the study by Kuhn et al. (1998), most of these studies have investigated legibility for paper- or screen-based reading tasks rather than for larger-format signs.

Fonts can also differ in their geometric characteristics (e.g., aspect ratio, stroke width, etc.). The width of the individual characters seems to have a large impact on legibility, larger than stroke width or the spacing between characters for both printed text and signs (Young et al., 1992; Garvey et al., 2001). Further, character width seems to influence the relationships between factors like the spacing between characters and legibility; reducing space between characters may be beneficial for wider characters, but detrimental for narrow ones in printed text (Young et al., 1992). Some guidelines suggest that when a sign character's width and height are the same, its legibility is maximized (CIDEA, 2010). While it may be a less important factor than character width, stroke width has received much interest in the research literature leading to guidelines for optimal stroke width (Forbes et al., 1965; Tinker, 1966; Kuhn et al., 1997; Holick and Carlson, 2002). One recommendation is that stroke width be 18% of the character height (Tinker, 1966), but even this factor interacts with others like the contrast polarity of the text (Kuhn et al., 1997). A font factor that impacts legibility for "dotted" fonts like those used in exposed-lamp or matrix signs is the spacing between lamps or matrix elements; Rea (2000) provides guidelines on spacing between elements for ensuring legibility.

Obviously, the size of text influences legibility (Rea and Ouellette, 1991). Unsurprisingly, many studies using visual display and sign contexts (Duncanson, 1994; Bernard et al., 2001; Ullman et al., 2005; Bullough and Skinner, 2016) suggest that larger letter sizes result in improved legibility, but the range of conditions used in those studies are important for generalization of these findings, since some authors report that there is a range of letter sizes above which legibility of printed text can degrade (Carter et al., 1985). A wealth of guidelines derived from research with on-premise signs (Bertucci, 2006; CIDEA, 2010; Bertucci and Crawford, 2015) and employed in municipal and other standards on font size exist, most specifying minimum letter size (City of West Hollywood, 2002; U.S. SBA, 2003; FHWA, 2004; ISA, 2007; Town of Huntersville, 2009; Millar, 2011), but sometimes recommending a range of appropriate sizes (Carter et al., 1985; Town of Bermuda Run, 2013). Most of the time, the letter height is used to quantify the letter size, but as found by Rea and Ouellette (1991) and Cai and Green (2009), the projected area of the character is a more complete specification of the size of the stimulus for letters and symbols on signs.

Other properties of sign characters aside from font and size influence legibility. The contrast of letters against the sign itself is one of the most critical (Rea and Ouellette, 1991; Schnell et al., 2004). Similar to research on letter size, higher contrast of display symbols and characters is generally thought to improve legibility (Shurtleff et al., 1966) and this is included in municipal sign standards (City of West Hollywood, 2002; Town of Huntersville, 2009; City of Davis, 2010) but some sources report an optimal contrast value, perhaps to avoid excessive brightness of characters or of the sign (see "Photometric, Colorimetric and Temporal Characteristics"). For example, Kuhn et al. (1997) report that the contrast between an on-premise sign and its characters best supports legibility when the luminance ratio between the brighter and the less bright of the two is 12:1. Importantly, it should be recalled that luminance contrast differs from color contrast; green letters on a red sign might have no luminance contrast but could still be visible because of the difference in colors. However, luminance contrast of printed text or of highway sign characters is substantially more important to legibility than color contrast (Forbes et al., 1965; Tinker, 1966), which only significantly affects legibility when the luminance contrast is low (Eastman, 1968), a situation that should be avoided in signs.

The polarity of contrast can also impact the degree of legibility a sign or other printed text exhibits. A majority of the research evidence reviewed (Tinker, 1966; Kuhn et al., 1997, 1998; CIDEA, 2010) is consistent of the notion that positive contrast (letters with higher luminances than the sign face) offers better legibility than negative contrast text. Because of this municipal guidance seems to favor positive contrast text (Town of Bermuda Run, 2013). Nonetheless, there are several reports that report no difference in legibility between positive and negative contrast text (Shurtleff et al., 1966; Lerner and Collins, 1983).

Contrast can also be a factor within individual characters on a sign, particularly for illuminated signs. Freyssinier et al. (2003) conducted evaluations of internally-illuminated sign letters and found that they began to be judged as unacceptable when the luminance contrast within different portions of the letters exceeded 0.2-0.4. Intentional contrast variations within letters occur when letters and other characters are rendered in an outline form rather than as a solid character. All of the research that has investigated the relative impact of outline versus solid letters has found outline characters to provide less legibility than solid ones (Lerner and Collins, 1983; Duncanson, 1994; Arditi et al., 1997), whether for printed text, visual displays or signs.

Finally, many investigations have been conducted regarding the use of all-uppercase versus mixed-case text on signs. In principal, because uppercase letters are larger than lowercase, the legibility of individual uppercase letters ought to be better than that of lowercase letters, and one investigation using single short, isolated words on an otherwise empty display screen did find slight advantages to displaying those words in all-uppercase text (Kinney and Showman, 1967). Nonetheless, most researchers who have investigated this question concluded that mixed-case text on displays and on signs improves legibility (Carter et al., 1985; Kuhn et al., 1997; Bertucci and Crawford, 2015), because it better differentiates among word-forms that would otherwise be similar using all-uppercase text. Accordingly, municipal guidance (Town of Bermuda Run, 2013) recommends mixed-case text for on-premise signs.

3. PHOTOMETRIC, COLORIMETRIC AND TEMPORAL CHARACTERISTICS

3.1. Conspicuity

Among the photometric properties of signs most related to conspicuity is the sign luminance (Elstad et al., 1962; Allen et al., 1967; Rea, 2000; AASHTO, 2005). In addition to ensuring that a sign is conspicuous, there are also concerns about ensuring that the luminance of a sign does not lead to distraction (ILE, 2001; Bullough and Skinner, 2011), especially among municipalities (City of Hutto, 2014; City of Mesa, undated). Table 1 summarizes research findings and recommendations from sign codes and standards regarding the range of luminances recommended for sign conspicuity while aiming to prevent distraction from overly bright signs, whether they are highway signs or commercial (on- or off-premise) signs.

Forbes (1972) developed a calculation method for estimating the detection distance of a highway sign, which uses the luminance of the sign (in contrast with the luminance of the ambient environment) as one of the factors crucial for detection. Not surprisingly, higher sign luminances tend to make highway signs easier to detect at night (Forbes et al., 1967) but not always in the daytime, where both dark signs and bright signs may be advantageous for conspicuity over intermediate sign brightness (Forbes et al., 1967), presumably because it is the contrast between a sign and its ambient environment that assists in detection (Kuhn et al., 1997).

The impact of sign luminance on conspicuity interacts with factors such as the visual complexity of the ambient environment (Schieber and Goodspeed, 1997) where improvements with higher luminance are only seen in the more complex visual environments, and this would explain why illumination levels recommended for signs are higher in brighter ambient environments (Rea, 2000). Increases in sign luminance have not always been accompanied by a higher proportion of appropriate driving maneuvers in response to roadway signs (Powers, 1965). It should also be noted that the color of a sign may impact its conspicuity; Gates et al. (2004) found advantages of fluorescent colors on highway signs in terms of the driving maneuvers that were exhibited when they were present, potentially indicating that those colors assisted in detecting the signs.

An approach for limiting the apparent brightness of a digital billboard sign was proposed by Lewin (2008). The illuminance from the sign at a particular distance from the sign along the road should not exceed 3 lx. This approach can allow the user to approximate the average luminance of a sign whose dimensions are known, but it cannot identify whether the luminance of the brightest portion of the sign might be judged excessive by observers. This is important because in a study of large-area light sources, ratings of the discomfort glare depend not only on the illuminance from the source but the maximum luminance of that source. Two light sources with the same average luminance can differ substantially in the amount of discomfort glare they produce (Bullough and Sweater Hickcox, 2012). If this finding can be extended to signs, quantifying the illuminance alone from a sign might not be sufficient to avoid problems.

An additional factor that can influence a sign's conspicuity is the presence of flashing, moving or animated content on the sign. Temporal changes in luminance or color will make a display or sign more conspicuous (Crawford, 1962; Forbes et al., 1965) and will attract more glances from drivers than static sign content on advertising signs (Beijer et al., 2004). Despite little hard evidence that dynamic advertising sign content reduces driving safety in terms of crashes (Smiley et al., 2005), many municipal codes prohibit flashing or moving sign content (City of Melbourne, 2009; City of Davis, 2010; City of Hutto, 2014; City of Mesa, undated) to avoid distraction from overly conspicuous commercial signage.

Source	Minimum Luminance (cd/m²)	Maximum Luminance (cd/m²)	Relevant Conditions
Allen et al. (1962)	35	100	Night, rural
	70	340	Night, illuminated highway
	700	1700	Night, very bright urban
AASHTO (2005)	20	40	Night, low ambient brightness
	45	90	Night, medium ambient brightness
	90	180	Night, high ambient brightness
Bullough and Skinner (2011)		280	Night
		23,000	Day
City of Hutto (2014)		500	Night
		7000	Day
City of Mesa (undated)		1125 red 2250 green 1675 amber 2500 full color	Night
		3150 red 6300 green 4690 amber 7000 full color	Day
Elstad et al. (1962)	35	70	Night, rural or suburban
	250	400	Night, bright urban
ILE (2001)		300	Night, large sign, low ambient brightness
		600	Night, large sign, medium/high ambient brightness
		100	Night, small sign, intrinsically dark area
		600	Night, small sign, low ambient brightness
		800	Night, small sign, medium ambient brightness
		1000	Night, small sign, high ambient brightness
Rea (2000)	70	350	Night, lighted fascia
	250	500	Night, bright fascia
	450	700	Night, low ambient brightness
	1000	1400	Night, average commercial area
	1400	1700	Night, emergency traffic control

Table 1. Sign luminance recommendations for conspicuity and minimizing distraction.

3.2. Legibility

Sign luminance can have important effects on legibility. Recommendations for highway and commercial sign luminances to ensure legibility are shown in Table 2. Luminances need to be high enough to ensure adequate readability, but if luminances are too high, legibility can be reduced (Garvey et al., 2009) by factors such as irradiation (Cornog and Rose, 1967). Increasing luminance can sometimes help counteract reduced visibility caused by factors such as small letter size (Tinker, 1966), but if legibility is already high, increasing luminance may have little effect on further legibility improvements (Bullough and Skinner, 2016). Several studies have investigated the interactions between luminance and other factors such as typographic and observer characteristics (Yager et al., 1998; Holick and Carlson, 2002; Schnell et al., 2004, 2009) for highway signs and visual displays. The uniformity of sign luminance can also influence legibility, and recommendations for uniformity as well as its absolute value can be found for highway signs (AASHTO, 2005).

Source	Minimum Luminance (cd/m^2)	Optimal Luminance (cd/m^2)	Relevant Conditions
Allen (1958)		35	Night, rural
Charness et al. (1999)		100	For reading
Fletcher et al. (2009)		20	Dark conditions, character luminance, positive contrast
		60	Bright conditions, character luminance, positive contrast
		1	Positive contrast
Freyssinier et al. (2006)		40-190	No adjacent signs present
		65-230	Adjacent signs present
Graham et al. (1997)		30	Night, younger observer from 90 m
		2	Night, younger observer from 60 m
		40	Night, older observer from 90 m
		7	Night, older observer from 60 m
Kuhn et al. (1997)	2.4	75	Night
Shurtleff et al. (1966)		70-140	For reading

Table 2. Minimum and optimal sign luminance recommendations for legibility.

In addition to luminance, the impacts of sign color(s) on legibility have also been addressed, albeit in a more limited manner than luminance. Funkhouser et al. (1999) compared green and purple traffic signs during daytime and nighttime driving tests and found drivers responded to them equivalently. Flashing or animated content, while increasing conspicuity (see above) will also tend to make text on visual displays more difficult to read (Milburn and Mertens, 1997), and this is probably also the case for outdoor signs.

The type of lighting used on illuminated signage will strongly influence the ease with which the sign can be read. Kuhn et al. (1998) and Garvey and Kuhn (2011) report that internally-illuminated and neon commercial signs provide superior legibility to externally-illuminated signs. This is also reflected in municipal standards that indicate a preference for internal or back-lighting over external illumination (City of Bellflower, 2016) for signs. However, some municipalities also discourage the use of neon signage (City of West Hollywood, 2002; City of Davis, 2010). The potential influence of taste or aesthetics in municipal sign codes is not fully understood and could underlie some of these recommendations.

Possible reasons for reduced legibility with external illumination systems include the potential for glare, which is why many standards require external light sources used to illuminate commercial and highway signs to be shielded from view (City of West Hollywood, 2002; AASHTO, 2005; City of Davis, 2010). External lighting might also serve as a distraction from the message content on a sign, so it should be designed to be as inconspicuous as possible (City of Saratoga Springs, 2012). Because of such difficulties with external lighting, as well as challenges with maintenance and costs like energy use, highway signs often use retroreflective sign sheeting materials in lieu of lighting to support nighttime legibility (Bullough et al., 2010). Retroreflectivity does not seem to be commonly used in on-premise or advertising signs.

4. ENVIRONMENTAL CHARACTERISTICS

4.1. Conspicuity

Not all factors that alter the visibility of signs are under the direct control of sign designers. In addition to the characteristics of the observer described previously in this paper, the environment in which a sign is located can strongly affect its visibility. In terms of sign conspicuity, one factor that will impact the conspicuity of a sign is the ambient brightness level, which can lead to different recommendations for sign or display luminance (Elstad et al., 1962; Rea, 2000; ILE, 2001; AASHTO, 2005; Fletcher et al., 2009) or the illuminance on signs (Rea, 2000), as illustrated by many of the findings listed in Table 1. Indeed, the contrast between a highway or an on-premise sign and its ambient background is an important predictor of how far away the sign can be detected (Forbes, 1972; Kuhn et al., 1997), such that the darkest and brightest signs may be most conspicuous against daytime background conditions (Forbes et al., 1967) but signs similar in luminance to the background will be less conspicuous.

The degree of visual complexity where a sign is located will also impact how easily it can be detected. For example, under visually simple conditions, traffic sign detection distances were reported by Akagi et al. (1996) to be nearly twice their value under visually complex conditions.

4.2. Legibility

The ambient environmental conditions play an important role in the legibility of signs. One of the more obvious factors may be daytime versus nighttime. Even though many signs at night are equipped with some type of illumination (e.g., internal, back-lighting or external), legibility distances under daytime conditions will tend to be substantially longer than under nighttime conditions (Zwahlen and Schnell, 1998; Ullman et al., 2005; Garvey et al., 2009) whether they are highway signs or on-premise signs.

The visual complexity of the ambient environment not only impacts a sign's conspicuity, but also its legibility. Bertucci and Crawford (2015) stated that it is necessary to reduce the legibility index (the distance at which a sign of a given size can be read) under medium-to-high-complexity visual environments, relative to low-complexity environments. Freyssinier et al. (2006) found that the luminances needed to achieve high levels of sign readability increased when an internally-illuminated sign was adjacent to other nearby signs, compared to when the same sign was visually isolated from other signs.

The viewing geometry and location of a sign will also influence the degree to which it can be easily read. An important factor related to signage is the viewing angle. Highway signs, for instance, are generally mounted such that the sign face is perpendicular to the lines of sight for oncoming traffic, while some building-mounted signs are mounted with the sign face nearly parallel to the line of sight. This reduces the projected solid angle of letters in the direction of a driver trying to read a sign or display (Cai and Green, 2009) even if the letter height is unchanged, and will accordingly reduce its legibility. Garvey (2006) reports that the legibility of commercial signs begins to be compromised when the viewing angle exceeds 20^{o}-40^{o} from the perpendicular to the line of sight.

Finally, the specific location of the sign can also make it more or less legible, perhaps because of driver expectations about where signs are likely to be located. Since many signs are located along the right-hand side of the road (in locations with right-side traffic patterns), drivers may be less attentive to signs on the left-hand side of the road, and it has been estimated (U.S. SBA, 2003) that commercial signs mounted on the left side of the road require letters to be larger to achieve equivalent legibility as signs on the right side.

5. SUMMARY

This review has identified several sources of technical research, industry rules of thumb and best practices, and consensus-based standards and codes, which describe how sign properties can affect visibility in terms of conspicuity and legibility, at least for the context of acquiring mainly textual information from commercial and traffic signs. Not included in this review are legal cases in which the results of research studies or requirements from municipalities have been tested by a court. Such a review could clarify the extent to which the findings summarized here can be generalized to different types of signs and signage applications.

From this review, it seems feasible that visual performance modeling can be used to predict the visibility of signs. However, current models may be incomplete regarding the influence of factors beyond luminance, size and contrast of signs and sign characters. Certainly, as described above, the characteristics of the observer (e.g., age, impairment, distraction) can confound any model predictions of a sign's conspicuity or legibility.

But even for model observers with good vision and who are attentive to signs, models of conspicuity or legibility can still have shortcomings. For example, highway sign characters subtending similar solid angles, and with similar photometric characteristics, will not yield similar legibility distances (Garvey et al., 2016). A fruitful area of exploration may be in developing quantitative adjustment factors relating the aspect ratio of sign characters to visual performance when size, luminance and contrast are held constant. Another factor that has not been considered in much of the reports reviewed here is the role of a sign's maximum luminance or luminance distribution on the noticeability of the sign or its potential to create distraction or glare. Subsequent investigation could explore this factor in an experimental setting.

6. ACKNOWLEDGMENTS

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7. REFERENCES AND ANNOTATIONS

Akagi Y, Seo T, Motoda Y. 1996. Influence of visual environments on visibility of traffic signs. Transportation Research Record 1553: 53-58.

- The average detection distances for signs decreased from 110 ft with minimum visual noise to 60 ft with high levels of visual noise.

Allen TM. 1958. Night legibility distances of highway signs. Highway Research Bulletin 191: 3-40.

- Optimal sign luminances for nighttime legibility were found to be around 35 cd/m².

Allen TW, Dyer FN, Smith GM, Janson MH. 1967. Luminance requirements for illuminated signs. Highway Research Record 167: 16-37.

- Minimum nighttime sign luminances of 35 cd/m² are appropriate in rural locations, with a maximum of 100 cd/m².
- On illuminated highways or in the presence of substantial glare from opposing vehicle headlights, sign luminances between 70 and 340 cd/m² are recommended.
- In very brightly lighted urban locations, a minimum luminance of 700 cd/m² with a maximum of 1700 cd/m² might be appropriate.

American Association of State Highway and Transportation Officials. 2005. Roadway Lighting Design Guide. Washington, DC: American Association of State Highway and Transportation Officials.

- Nighttime sign luminances in areas of low, medium and high ambient luminance should be 20-40 cd/m², 45-90 cd/m² and 90-180 cd/m², respectively.
- A maximum-to-minimum sign luminance ratio of 6:1 is recommended.
- External lighting, if used, should not direct light into drivers' eyes.

Arditi A, Cho J. 2005. Serifs and font legibility. Vision Research 45: 2926-2933.

- Reading speed for normal-sighted and low vision observers did not differ whether fonts has serifs or not.
- Acuity was slightly improved when a font with serifs was used in place of one without serifs.

Arditi A, Liu L, Lynn W. 1997. Legibility of outline and solid fonts with wide and narrow spacing. Trends in Optics and Photonics, 5 p.

- Acuity for outline fonts was worse for outline fonts than for solid fonts.
- Outline characters needed to be 1.8 times larger than solid characters for equivalent legibility.

Beijer D, Smiley A, Eizenman M. 2004. Observed driver glance behavior at roadside advertising signs. Transportation Research Record 1899: 96-103.

- Signs with dynamic content made up half of the signs observed in one study, but received 70% of glances by drivers.
- Active signs received twice as many glances as non-active ones.

Bernard M, Liao CH, Mills M. 2001. The effects of font type and size on the legibility and reading time of online text by older adults. Proceedings of the Conference on Human Factors in Computing Systems, pp. 175-176.

- On average, legibility by older people of 14-point type was greater than for 12-point type.
- A 12-point serif font was less legible than a 12-point non-serif font, but the reverse effect of serifs occurred at 14 points.

Bertucci A. 2003. On-Premise Signs: Guideline Standards. Bristol, PA: United States Sign Council Foundation.

- A methodology for calculating the necessary size of a sign for various conditions (e.g., vehicle speed, type of reaction needed, letter type) is presented.

Bertucci A. 2006. Sign Legibility: Rules of Thumb. Bristol, PA: United States Sign Council Foundation.

- A legibility index of 30 ft/in is recommended for signage.

Bertucci A, Crawford R. 2015. Best Practice Standards for On-Premise Signs. Bristol, PA: United States Sign Council Foundation.

- Letter height needs to increase by 15% when all-uppercase letters are used, compared to mixed case.
- A legibility index of 30 ft/in. is recommended for adequate sign legibility.
- In conditions of moderate visual complexity, the recommended legibility index should be multiplied by 0.83; under high complexity, the legibility index should be multiplied by 0.67.

Bullough JD, Skinner NP. 2011. Luminance criteria and measurement considerations for light-emitting billboards. Transportation Research Board Annual Meeting, 7 p.

- A maximum allowable daytime billboard luminance of 23,000 cd/m² is proposed.
- A maximum allowable nighttime billboard luminance of 280 cd/m² is proposed.

Bullough JD, Skinner NP. 2016 [in press]. High visibility reflective sign sheeting materials: Field and computational evaluations of visual performance. Transport, 9 p.

- The relative visual performance model shows that large changes in luminance have small impacts on visibility for highway signs.
- Font size is a primary reason signs are not legible from large distances.

Bullough JD, Skinner NP, O'Rourke CP. 2010. Legibility of urban highway traffic signs using new retroreflective materials. Transport 25: 229-236.

- Retroreflective materials can compensate for a lack of external sign illumination in overhead guide signs.

Bullough JD, Sweater Hickcox K. 2012. Interactions among light source luminance, illuminance and size on discomfort glare. Society of Automotive Engineers International Journal of Passenger Cars - Mechanical Systems 5(1): 199-202.

- Ratings of discomfort glare from large-area sources are influenced by the illuminance produced by the source at observers' eyes and by the maximum luminance of the source of glare.

Cai H, Green PA. 2009. Legibility index for examining common viewing situations: A new definition using solid angle. Leukos 5(4): 279-295.

- A legibility index based on the subtended solid angle of a sign character rather than its height is proposed,
- The revised legibility index performed well at predicting critical legibility levels for many different viewing angles in which the characters' subtended angle would differ.

Carter R, Day B, Meggs P. 1985. Typographic Design: Form and Communication. New York, NY: Van Nostrand Reinhold.

- Text in all-uppercase letters is more difficult to read than mixed-case text.
- Serif and non-serif fonts can provide equal legibility.
- Research is described that finds the optimal font size at normal reading distances to be 9-12 points.

Center for Inclusive Design and Environmental Access. 2010. Design Resources: Text Legibility and Readability of Large Format Signs in Buildings and Sites, DR-11. Buffalo, NY: University at Buffalo.

- Research is cited stating that setting letter width to be the same as letter height results in greater legibility distances.
- A legibility index of 35 ft/in. is recommended.
- Positive contrast text is recommended.

Charness N, Dijkstra K., 1999. Age, luminance, and print legibility in homes, offices, and public places. Human Factors 41(2): 173-193.

- Reading task background luminances of 100 cd/m² are recommended for proficient reading.

City of Bellflower. 2016. Signage Design Guidelines. Bellflower, CA: City of Bellflower.

- Intricate typefaces for signs are prohibited.
- Lettering on a sign should not occupy more than 75% of the sign face area.
- The number of colors used on a sign should not exceed three.
- Excessively bright and fluorescent colors should be avoided.
- Internally-illuminated or back-lighted signs are preferred over external illumination.

City of Davis. 2010. Davis Citywide Sign Design Guidelines. Davis, CA: City of Davis.

- Messages on signs should be brief.
- Letters should occupy no more than 75% of the sign face area.
- High contrast between letters/symbols and their backgrounds should be used.
- External lighting should be shielded from view.
- Neon light signs are discouraged.
- Animation, blinking or other changes in intensity and color are prohibited.

City of Hutto. 2014. Site Design Standards. Hutto, TX: City of Hutto.

- Blinking or flashing on signs is prohibited.
- Electronic signs should not exceed a luminance of 7000 cd/m² during the daytime and 500 cd/m² during the nighttime.

City of Melbourne. 2009. An Ordinance of the City of Melbourne, Brevard County, Florida, Relating to Signs and Advertising. Melbourne, FL: City of Melbourne.

- Rotating or animated signs (except for changeable copy) are prohibited.

City of Mesa. [Undated.] Sign Regulations. Mesa, AZ: City of Mesa.

- Signs with flashing illumination or other animation or movement are prohibited.
- A sign with an LED display cannot exceed a luminance of 3150, 6300, 4690 or 7000 cd/m² for red, green, amber or full color signs, respectively, during daytime; or 1125, 2250, 1675 or 2500 cd/m² for red, green, amber or full color signs, respectively, during nighttime.
- Light sources for any external illumination should not be directly visible.

City of Saratoga Springs. 2012. Signage: Historic District Design Guidelines. Saratoga Springs, NY: City of Saratoga Springs.

- Sign messages should be short (no more than 8 words) and use three or fewer colors.
- Light sources for external illumination should be inconspicuous.

City of West Hollywood. 2002. Sign Design Guidelines. West Hollywood, CA: City of West Hollywood.

- Contrasting colors between letters and the sign background should be used to maximize legibility.
- An excessive number of sign colors can reduce legibility.
- A sign designed to be viewed from 60 ft requires 3.5 in. letters; to be viewed from 100 ft requires 5.5-6 in. letters.
- Symbols and pictograms are stated to be more effective than text.
- Letters should not take up more than 75% of the space on a sign panel.
- External sign lighting should be shielded to avoid glare; back lighting is encouraged.

Cornog DY, Rose FC. 1967. Legibility of Alphanumeric Characters and Other Symbols, II: A Reference Handbook. Washington, DC: National Bureau of Standards.

- Excessive brightness of a display can lead to irradiation that reduces legibility of characters and symbols.

Crawford A. 1962. The perception of light signals: The effect of the number of irrelevant lights. Ergonomics 5: 417-428.

- Flashing lights increase their conspicuity relative to steady lights.

Duncanson JP. 1994. Visual and Auditory Symbols: A Literature Review. Atlantic City, NJ: Federal Aviation Administration.

- It is proposed that an effective sign symbol is simple rather than complex, large rather than small, and solid rather than hollow or outlined.

Eastman AA. 1968. Color contrast versus luminance contrast. Illuminating Engineering 63: 67.

- Color contrast has little to no influence on visibility of objects unless the luminance contrast approaches zero.

Elstad JO, Fitzpatrick JT, Woltman HL. 1962. Requisite luminance characteristics for reflective signs. Highway Research Bulletin 336: 51-60.

- Optimal nighttime sign luminances were found in rural and suburban locations to be between 35 and 70 cd/m^2.
- In bright urban locations, nighttime sign luminances between 250 and 400 cd/m^2 were judged as prominently visible.

Federal Highway Administration. 2004. Standard Highway Signs. Washington, DC: Federal Highway Administration.

- Guide signs on conventional roads in rural locations should have letters at least 6 in. high; in urban locations with low speed limits (25 mph) letter height should be at least 4 in.
- Street name signs should have a letter height of 6 in.
- For signs other than on interstate highways, a legibility index of 40 ft/in. should be used.
- Nearly all signs should have borders of the same color as the sign letters.

Fletcher K, Sutherland S, Nugent K. 2009. Identification of Text and Symbols on a Liquid Crystal Display, Part II: Contrast and Luminance Settings to Optimise Legibility. Edinburgh, Australia: Defence Science and Technology Organisation.

- For a positive contrast display, character luminance is recommended to be 20 cd/m^2 under dark lighting conditions, and 60 cd/m^2 under bright conditions.
- The background screen luminance is recommended to be 1 cd/m^2.

Forbes TW. 1972. Visibility and legibility of highway signs. In Human Factors in Traffic Safety Research. New York, NY: Wiley.

- A formula relating the conspicuity detection distance for a sign to its luminance, the contrast between the sign letters and their background, and the letter height is provided.

Forbes TW, Pain RF, Fry JP, Joyce RP. 1967. Effect of sign position and brightness on seeing simulated highway signs. Highway Research Record 164: 29-37.

- At night, higher sign luminance tended to be more likely to be detected.
- Under daytime conditions, darker signs were often most likely to be detected, but so were brighter signs, for many observers. The contrast between letters and the sign background might sometimes overcome the contrast between the sign and its own background.

Forbes TW, Snyder TE, Pain RF. 1965. Traffic sign requirements: I. Review of factors involved, previous studies and needed research. Highway Research Record 70: 48-56.

- Research is cited finding about 85% legibility to signs with a legibility index (ft of legibility distance per in of letter height) of 50 ft/in.
- Only 3-4 short, familiar words can be read in a single glance at a sign.
- Letter-height to stroke-width ratios of 4-6 appear to be optimal for legibility.
- Color combinations providing the highest luminance contrast tend to provide the highest legibility.
- Use of fluorescent colors appears to have some advantages for sign detection.
- Brightness changes and motion are salient cues for peripheral vision.

Freyssinier JP, Narendran N, Bullough JD. 2006. Luminance requirements for lighted signage. Proceedings of the SPIE, Vol. 6337, 63371M.

- Illuminated sign luminances between 40 and 190 cd/m² are optimal when no nearby signs are present.
- Illuminated sign luminances between 65 and 230 cd/m² are optimal when nearby signs are present.

Freyssinier JP, Zhou Y, Ramamurthy V, Bierman A, Bullough JD, Narendran N. 2003. Evaluation of light-emitting diodes for signage applications. Proceedings of the SPIE, Vol. 5187, pp. 309-317.

- The contrast of luminance variations within a sign character should be no greater than 0.2-0.4 to achieve 80% acceptability.
- The size or spatial frequency of the luminance variations are relatively unimportant to judgments of acceptability.

Funkhouser D, Chrysler S, Nelson A, Park ES. 2008. Traffic sign legibility for different sign background colors: Results of an open road study at freeway speeds. Proceedings of the Human Factors and Ergonomics Society 52nd Annual Meeting, pp. 1855-1859.

- Green and purple highway signs performed equivalently in a driving test in terms of legibility distances during daytime and nighttime.

Garvey PM. 2006. On-Premise Signs: Determination of Parallel Sign Legibility and Letter Heights. Bristol, PA: United States Sign Council Foundation.

- Reading performance begins to decline as the viewing angle changes from perpendicular with the sign surface to between 20^{o} and 40^{o} from perpendicular.

Garvey PM. 2007. Urban wayfinding signs: Evaluating exceptions to FHWA's standard alphabet. Transportation Research Board Annual Meeting, 17 p.

- A study of the use of the Futura font in wayfinding signs in Miami Beach found that it resulted in equivalent legibility as standard highway sign fonts.

Garvey PM, Chirwa KN, Meeker DT, Pietrucha MT, Zineddin AZ, Ghebrial RS, Montalbano J. 2004. New font and arrow for National Park Service guide signs. Transportation Research Record 1862: 1-9.

- A new highway sign font resulted in smaller word "footprints" but increased legibility distances by 10%.

Garvey PM, Klena MJ, Eie W-Y, Meeker DT, Pietrucha MT. 2016. Legibility of the Clearview typeface and FHWA standard alphabets on negative- and positive-contrast signs. Transportation Research Record 2555: 28-37.

- Signs using the Clearview font outperformed identical signs using standard highway alphabets in terms of legibility distance.
- Predictions of relative visual performance were correlated with legibility distances for individual fonts, but legibility distances were lower than predicted by the visual performance model when the font aspect ratio was narrow.

Garvey PM, Kuhn BT. 2011. Highway sign visibility. In Handbook of Transportation Engineering (Kutz M, editor). New York, NY: McGraw-Hill.

- Internally-illuminated signs and neon signs resulted in 40%-60% improvements in nighttime legibility over externally-illuminated signs.

Garvey PM, Pietrucha MT, Cruzado I. 2009. The Effects of Internally Illuminated On-Premise Sign Brightness on Nighttime Sign Visibility and Traffic Safety. Bristol, PA: United States Sign Council Foundation.

- Recognition distances at night to signs tend to increase as sign luminance increases, but decrease at the very highest luminances.
- Daytime signs were 43% more legible than poor nighttime signs, but only 13% more legible than well designed nighttime signs.

Garvey PM, Pietrucha MT, Meeker D. 1997. Effects of font and capitalization on legibility of guide signs. Transportation Research Record 1605: 73-79.

- Nighttime legibility distances to highway signs increased by 16% when Clearview font was used in place of the standard highway font.

Garvey PM, Zineddin AZ, Pietrucha MT. 2001. Letter legibility for signs and other large format applications. Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting, pp. 1443-1447.

- A study of visual acuity using various fonts found Bank Gothic Light, Dutch Regular and Dutch Bold to be most legible, with Commercial Script Regular least legible.
- Letter width serves as a better predictor of legibility than stroke width.

Gates TJ, Carlson PJ, Hawkins HG. 2004. Field evaluations of warning and regulatory signs with enhanced conspicuity properties. Transportation Research Record 1862: 64-76.

- Use of fluorescent colors in highways signs increased desired driving maneuvers.
- A red border around speed limit signs reduced daytime driving speeds and reduced the number of speed violators during daytime and nighttime.

Goodspeed C, Rea MS. 1999. The significance of surround conditions for roadway signs. Journal of the Illuminating Engineering Society 28(1): 164.

- The speed with which observers could identify Landolt ring target orientation was correlated with the predicted relative visual performance model quantity.

Graham JR, Fazal A, King LE. 1997. Minimum luminance of highway signs required by older drivers. Transportation Research Record 1573: 91-98.

- Young drivers require sign luminances of 30 cd/m² for correct identification from 90 m, and 2 cd/m² from 60 m.
- Older drivers require sign luminances in excess of 40 cd/m² for correct identification from 90 m, and 7 cd/m² from 60 m.

Hawkins HG, Picha DL, Wooldridge MD, Greene FK, Brinkmeyer G. 1999. Performance comparison of three freeway guide sign alphabets. Transportation Research Record 1692: 9-16.

- A comparison of different highway sign fonts showed increased legibility with Clearview over the standard highway font; the advantage was between 2% and 8%.

Hawkins HG, Rose ER. 2005. A human factors study of the effects of adding dual logo panels to specific service signs. Transportation Research Board Annual Meeting, 18 p.

- Using two logos in the space normally allocated to a single logo on service signs resulted in lower recognition, but not so much that using dual logos should be prohibited in the authors' opinion.

Holick AJ, Carlson PJ. 2002. Model of overhead-sign luminance needed for legibility. Transportation Research Record 1801: 80-86.

- An equation for the sign luminance needed to achieve legibility as a function of driver age, visual acuity, stroke width and viewing distance is provided.

Institution of Lighting Engineers. 2001. Brightness of Illuminated Advertisements. Warwickshire, UK: Institution of Lighting Engineers.

- Large illuminated sign luminance at night should be limited to 300 cd/m² in low district brightness areas and 600 cd/m² in medium and high district brightness areas; large illuminated signs should not be used in intrinsically dark areas.
- Small illuminated sign luminance at night should be limited to 100 cd/m² in intrinsically dark areas, 600 cd/m² in low district brightness areas, 800 cd/m² in medium district brightness areas and 1000 cd/m² in high district brightness areas.

International Sign Association. 2007. Conspicuity and readability. Signline 51: 1-8.

- At a speed of 55 mph, a sign should be legible from a distance of 440 ft; at a speed of 30 mph, it should be legible from 240 ft.
- On-premise signs should use letter heights of 7 in. for traffic at 25 mph, and 15 in. for traffic at 55 mph.

Kinney GC, Showman DJ. 1967. Studies in Display Symbol Legibility: Part XVIII. The Relative Legibility of Uppercase and Lowercase Typewritten Words. Bedford, MA: The Mitre Corporation.

- Word forms produced by combinations of uppercase and lowercase letters were equivalent in legibility to those by all-uppercase letters.
- Uppercase letters are recommended for displays and applications other than "normal reading" of text.

Kuhn BT, Garvey PM, Pietrucha MT. 1997. Model guidelines for visibility of on-premise advertising signs. Transportation Research Record 1605: 80-87.

- The contrast between a sign and its immediate background is the primary determinant of one's ability to detect the sign in visually simple environments, perhaps more than size.
- Increased sign luminance results in increased conspicuity and can help overcome visual complexity of the sign's background in most cases.
- Sign color can increase the sign's conspicuity.
- Contrast between sign letters and the sign background is important for legibility with a luminance ratio of 12:1 being close to optimal.
- Increasing sign luminance generally improves nighttime legibility up to an optimal value of 75 cd/m^2. Sign luminance at night should not be below 2.4 cd/m^2.
- Legibility distances for graphical symbols were nearly always longer than for alphanumeric characters.
- Mixed-case characters result in greater legibility distances than uppercase-only.
- The optimal stroke-width to height ratio for positive contrast is 1:5, and 1:7 for negative contrast text.
- Positive contrast results in greater legibility than negative contrast.
- To read a sign, process the information, and execute a driving maneuver in response to it requires 5.5 seconds with signs containing five or fewer critical elements.

Kuhn BT, Garvey PM, Pietrucha MT. 1998. Sign Legibility: The Impact of Color and Illumination on Typical On-Premise Sign Font Legibility. Bristol, PA: United States Sign Council Foundation.

- Internal illumination and neon signs outperformed externally-lighted signs in terms of sign legibility.
- Positive contrast signs outperformed negative contrast signs in terms of legibility.
- No legibility differences between serif and non-serif fonts were identified.

Lerner ND, Collins BL. 1983. Symbol sign understandability when visibility is poor. Proceedings of the Human Factors Society 27th Annual Meeting, pp. 944-946.

- The polarity of symbols and backgrounds made little difference on the recognition of symbolic signs.
- Filled symbols outperformed outline symbols in terms of recognition.

Lewin I. 2008. Digital Billboard Recommendations and Comparisons to Conventional Billboards. Scottsdale, AZ: Lighting Sciences, Inc.

- It is recommended that the illuminance from a digital billboard at a distance between 150 ft (for small billboards) and 350 ft (for very large billboards) not exceed 3 lx.

Milburn NJ, Mertens HW. 1997. Evaluation of a Range of Target Blink Amplitudes for Attention-Getting Value in a Simulated Air Traffic Control Display, DOT/FAA/AM-97/10. Washington, DC: Federal Aviation Administration.

- Flashing or blinking text is more difficult to read than steady text.

Millar K. 2011. Designing for legibility. SignCraft (January/February): 42-44.

- A rule of thumb for letter height at various viewing distances is given: 4 in. per 100 ft of viewing distance.
- At 30 mph, 8 in. letters are needed to ensure 5 seconds of readability; 4 in. letters ensure 3 seconds of legibility.
- At 60 mph, 16 in. letters are needed to ensure 5 seconds of readability; 8 in. letters ensure 3 seconds of legibility.

Pankok C, Kaber D, Rasdorf W, Hummer J. 2015. Driver attention and performance effects of guide and logo signs under freeway driving. Transportation Research Board Annual Meeting, 11 p.

- A comparison of guide signs and logo signs on the highway showed that guide signs received fewer and shorter visual fixations.
- Guide signs had more consistent eye-scan patterns than logo signs, probably because of the left-to-right nature of reading text on guide signs.

Powers LD. 1965. Effectiveness of sign background reflectorization. Highway Research Record 70: 74-86.

- Study participants were instructed to drive along a highway at night and exit following the presence of test signs equipped with no, low or highly-reflective green background sheeting material (resulting in different background luminances), with white reflectorized letters.
- No differences among the background conditions were found in terms of accuracy in responding to the test signs.

Rea MS (editor). 2000. IESNA Lighting Handbook: Reference and Application, 9th ed. New York, NY: Illuminating Engineering Society.

- Equations are provided for the spacing of individual lamps in exposed-letter signs, and for lamp wattages in different ambient environments.
- Sign luminance recommendations include 70-350 cd/m² for lighted fascia signs, 250-500 cd/m² for bright fascia signs, 450-700 cd/m² for low brightness areas, 700-1000 cd/m² for average commercial areas, 1000-1400 for areas with high sign competition, and 1400-1700 cd/m² for emergency traffic control.
- Floodlighted signs in bright surrounds should be illuminated to 1000 lx if reflectance is low, and 500 lx if reflectance is high; in dark surrounds, half these illuminances are recommended.

Rea MS, Ouellette MJ. 1991. Relative visual performance: A basis for application. Lighting Research and Technology 23(3): 135-144.

- The speed and accuracy of visual processing such as identifying characters in printed text is systematically related to its contrast, size, and the luminance of the background.

Schieber F, Goodspeed CH. 1997. Nighttime conspicuity of highway signs as a function of sign brightness, background complexity and age of observer. Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting, pp. 1362-1366.

- Increasing sign luminance had no benefit in terms of response times or response accuracy to signs when backgrounds were simple, but did improve detection times and accuracy in visually complex environments.

Schnell T, Atkan F, Li C. 2004. Traffic sign luminance requirements of nighttime drivers for symbolic signs. Transportation Research Record 1862: 24-35.

- Sign luminance, letter contrast and the type of symbol displayed all influenced the legibility distance of sign symbols.

Schnell T, Yekhshatyan L, Daiker R. 2009. Effect of luminance and text size on information acquisition time from traffic signs. Transportation Research Record 2122: 52-62.

- The relative visual performance model resulted in close agreement with visual acquisition times in a study of sign character legibility under different luminances, sizes and contrasts.

Shurtleff D, Botha B, Young M. 1966. Studies in Display Symbol Legibility: Part IV. The Effects of Brightness, Letter Spacing, Symbol Background Relation and Surround Brightness on the Legibility of Capital Letters. Bedford, MA: The Mitre Corporation.

- Letters with high contrast against their backgrounds are recommended for highest acuity.
- Polarity of contrast is unimportant to legibility.
- Background luminances of 70 to 140 cd/m² are recommended.

Smiley A, Persaud B, Bahar G, Mollett C, Lyon C, Smahel T, Kelman WL. 2005. Traffic safety evaluation of video advertising signs. Transportation Research Record 1937: 105-112.

- Video advertising is stated to have potential to distract drivers inappropriately, but overall impacts on safety are likely to be small.

Tinker MA. 1966. Experimental studies on the legibility of print: An annotated bibliography. Reading Research Quarterly 1(4): 67-118.

- Research is cited stating that letters with serifs are more legible than those without serifs.
- A study found that white numbers printed on a black background were 8% more legible than black numbers printed on a white background.
- The poorest color combinations for reading text were found in one study to be red type on black background, or vice versa. Luminance contrast is one of the most important factors in legibility.
- The optimal character stroke width was identified in research as being 18% of the character height or width.
- Research stating that increasing illumination could overcome a type size change from 12 to 6 points is cited.

Town of Bermuda Run. 2013. Sign Design Guidelines. Bermuda Run, NC: Town of Bermuda Run.

- A viewer reaction time of 8 seconds is recommended for signs along roads with a speak limit of 45 mph, when six or fewer words are on the sign.
- The ideal letter height for signs is stated to be between 8 and 13 in.
- For improved legibility, block (non-script) text and mixed case is preferred.
- Using no more than two colors is stated to increase legibility.
- Positive contrast signs are stated to increase legibility, but the degree of improvement depends upon illumination and contrast.

Town of Huntersville. 2009. Suggestions for Designing Effective Signs. Huntersville, NC: Town of Huntersville.

- High contrast between sign letters and their backgrounds is desirable for legibility.
- Light letters on dark backgrounds are preferable to the opposite for ease of reading.
- For 2-lane roads, 30 mph traffic requires 8-in. letters and 55 mph traffic requires 12-in. letters.
- For 4-lane roads, 30 mph traffic requires 10-in. letters and 55 mph traffic requires 15-in. letters.
- Sign letters should occupy no more than 40% of the sign area.

Ullman BR, Ullman GL, Dudek CL, Ramirez EA. 2005. Legibility distances of smaller letter light-emitting diode changeable message signs. Transportation Research Board Annual Meeting, 23 p.

- LED letters on a changeable message sign with a height of 9 in. were legible from 228 ft in the daytime and 114 ft at night.
- LED letters on a changeable message sign with a height of 10.6 in. were legible from 324 ft in the daytime and 203 ft at night.

U.S. Small Business Administration. 2003. The Signage Sourcebook. Washington, DC: U.S. Small Business Administration.

- It is recommended that a sign be legible from a distance (in ft) equal to a vehicle's speed limit (in mph) multiplied by 8.
- Signs mounted on the left side of the road require letters to be one-third larger than those on the right side of the road, for equal legibility.
- Recommended sign heights range from 12 ft for 25-mph traffic to 50 ft for 55-mph traffic.

Van Houten R, Healey K, Malenfant JEL, Retting R. 1998. Use of signs and symbols to increase the efficacy of pedestrian-activated flashing beacons at crosswalks. Transportation Research Record 1636: 92-95.

- Adding a pedestrian symbol sign near a flashing warning beacon increased the number of drivers who yielded to pedestrians.

Yager D, Aquilante K, Plass R. 1998. High and low luminance letters, acuity reserve, and font effects on reading speed. Vision Research 38: 2527-2531.

- At a high background luminance (150 cd/m²) there is no difference in reading rates between serif and non-serif fonts.
- At a low background luminance (0.15 cd/m²) a non-serif font resulted in improved reading rates over a serif font.

Young SL, Laughery KR, Bell M. 1992. Effects of two type density characteristics on the legibility of print. Proceedings of the Human Factors Society 36th Annual Meeting, pp. 504-508.

- Type width is stated to affect legibility more than inter-character spacing.
- Reducing the space between characters improved legibility for standard type widths, but decreased legibility for the narrowest fonts.

Zwahlen HT, Schnell T. 1998. Legibility of traffic sign text and symbols. Transportation Research Record 1692: 142-151.

- Sign legibility distances are 1.8 times longer in the daytime than they are at night.

A Study of Effectiveness of Midblock Pedestrian Crossings:
Analyzing a Selection of High-Visibility Warning Signs

Rebekka Apardian

Bhuiyan Monwar Alam
Associate Professor, Department of Geography & Planning, The University of Toledo,

Abstract

The purpose of this paper is to examine a selection of different high-visibility pedestrian warning signs at midblock crossings and summarize the most effective options, where effectiveness is measured by pedestrian safety. Four locations are observed. Effectiveness is measured by the vehicle yield percentage, the pedestrian conflicts, and pedestrian wait time. The findings largely concur with previous literature, concluding that speed and road width are important factors in determining a driver's likeliness to yield. This paper also hypothesizes that signage on both sides of the roadway and overhead signage also makes a positive visibility impact.

Keywords: pedestrian safety, midblock crosswalk, behavior, yield rate, high-visibility, warning signs

Introduction

Pedestrian safety must be a top priority within the transportation planning community as cities promote sustainable transportation, alternative travel modes, and healthy lifestyles. In order to maximize safety, all available options and methods must be analyzed and compared. In the case of a pedestrian street crossing, it is important to strategically install midblock pedestrian crossings at locations pedestrians may decide to jaywalk. These midblock crossings occur between intersections where a pedestrian would find it convenient to cross in the middle of the street rather than walk to the nearest intersection. This location presents an additional challenge for vehicle-pedestrian conflict that must be assessed. A driver is, in most cases, more used to looking for a crossing pedestrian at an intersection that at a midblock location. Vehicles may be moving at a quicker speed through midblock pedestrian crossings than through crossings at intersections where a driver may be either coming to a stop or starting to move after being stopped. This necessitates effective methods for ensuring a safe crossing and increased driver awareness at a mid-block crossing.

This paper examines pedestrian awareness/warning methods and their effectiveness at midblock crossings. These pedestrian awareness/warning methods often tend to be signs or signals, and can be either of a passive nature or of an active nature. A passive method is one that is static and does not change. Examples of this would be physical infrastructure, such as a raised crosswalk or fixed signage. An active method is dynamic and responds to its environment in order to facilitate safer crossing. For example, a pedestrian-actuated signal that stops traffic with a light when pushed would be considered an active method. The pedestrian awareness/warning methods studied specifically here include signals, signs, and pavement markings.

Literature Review

In general, it has been found that higher speeds and wider roadways result in increased pedestrian risk at a midblock crossing. A report by the National Cooperative Highway Research Program (NCHRP) noted that motorists are less likely to yield at a high speed and high vehicle volume crossing because they feel inconvenienced and as if the road is for the car, not the pedestrian, under these conditions. NCHRP further suggests that, due to the design of the roadway, motorists often feel as though yielding to a pedestrian is a courtesy rather than the law.

Studies done by the NCHRP found that motorist yielding rate at in-street "yield to pedestrian" signs was relatively high, ranging from 82-91%. These studies were done on all two-lane roads with slow speed limits (25-30 MPH). Huang, Zegeer, and Nassi also found that in-street signs that communicated the law requiring motorists to yield for pedestrians had a high yield rate. The signs in this study were also on low speed roads.

The literature concludes that there are higher yield rates for high-visibility signs, such as diamond-shaped signs with a black pedestrian graphic. For these, the NCHRP found that roads with a speed limit of 25 MPH saw an average motorist yielding rate of 61%. On 35 MPH roads, high-visibility signs saw an average yielding rate that dropped to 17%. This would suggest that speed is a very high indicator of motorist yielding.

Van Houten et. al. (1992) found that the introduction of a reflective sign reading, "stop here for pedestrians" with an arrow pointing towards the desired stopping point resulted in a decrease of pedestrian-vehicle conflicts by 50% at two different locations. A study by Palamarthy et al., 1994, found that group interactions were significant when determining an appropriate gap for crossing, suggesting safety increases with higher numbers of pedestrians.

Method

In order to study the effectiveness of passive signs for midblock crossings, four different studies were conducted. Each of these observations were done in fifteen-minute intervals. The data recorded for the signs include number of pedestrians per crossing group, the type of eventual crossing (allowed by a yielded vehicle, a gap in traffic occurred, or the pedestrian forced a vehicle to yield to them by crossing into traffic), and the number of vehicles that passed before a crossing was achieved by a waiting pedestrian. The crossing observations were categorized by the type of crossing that occurred when the pedestrian first entered the crosswalk. A near conflict is categorized by a near vehicle-pedestrian contact, as has been described in past research on conflict analysis (Palamarthy et. al). This can be in the form of a pedestrian jumping out of the way, a vehicle braking suddenly, swerving, or speeding in close proximity of a crossing pedestrian. The overall yield rate for each location was calculated by counting the number of vehicles who passed a waiting pedestrian (had the opportunity to yield) and the number of vehicles who actually yielded for the pedestrian. Forced yields are not included.

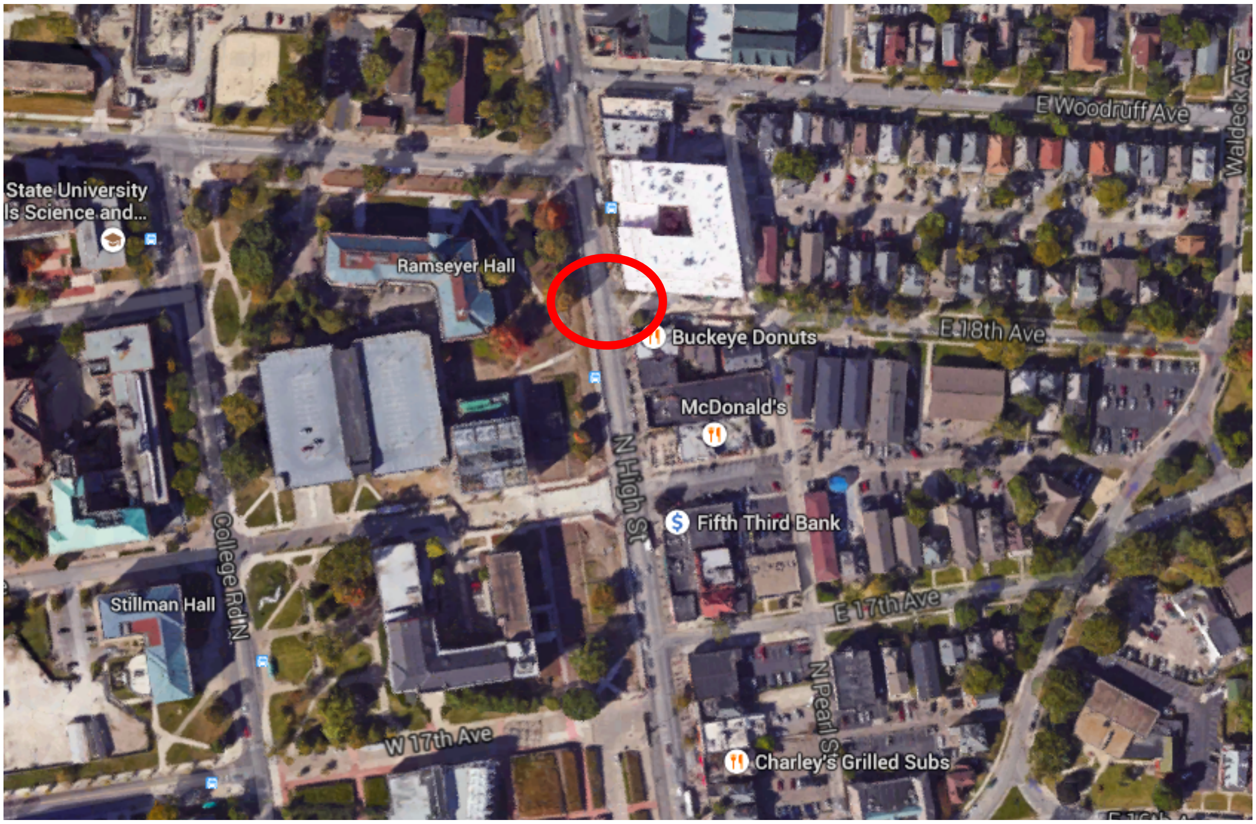
Observations

High Street Midblock Crossings

The first two studies were observations of midblock crossings on High Street in Columbus, Ohio. They are across from Ohio State University and lead from the university into retail, restaurants, and residential mixed land uses. There are four lanes of traffic (two in each direction) plus one turning lane. The far right lanes have “sharrows” (indicating that motorists should share the lane with bicycles) as painted markings in the middle of the lane and the posted speed limit is 25 MPH, though observations showed that most motorists drive 30-35 MPH through this area. The majority of pedestrians are students.

High-Visibility Signage on High Street at 18th Avenue

The first location, south of Woodruff Avenue and at about 18th Avenue, is shown in Map 1. This crossing has a diamond shaped pedestrian high-visibility sign side-mounted at the crosswalk, as shown in Figure 1. There is a “yield to pedestrians here” sign further upstream, pointing to a thick white line. The crosswalk is striped and visible. There is a row of triangles leading up to the crosswalk as well. These signs and pavement markings exist in both directions of travel.



Map 1: High Street, at about 18th Avenue across from Ohio State (Google Maps)

Figure 1: Crossing conditions on High Street south of Woodruff Avenue, at about 18th Avenue (Google Maps)

Table 1 shows the observations from this crossing. These observations revealed a low vehicle yield rate, similar to that of which the literature found with these standard signs. There were 14 crossing groups, totaling 24 pedestrians. The summary of the crossing data for this location are shown in Table 2. Of those crossing groups, eight (57.14%) made their eventual cross during a gap in traffic. Two (14.29%) were yielded to by a vehicle, and the remaining four (28.57%) crossed by stepping into the roadway and forcing traffic to yield to them. One near conflict occurred during a crossing, which happened at the opposite end from where the pedestrian began his crossing.

Table 1

Data from High-Visibility Signage Midblock Crossing Location #1				
Location: High Street, across from Ohio State University, south of W Woodruff Avenue, at about E 18th Avenue				
Design: Striped, (The following in each direction): Row of triangles painted on roadway approaching crosswalk, Diamond-shaped neon pedestrian sign, "Yield here to pedestrian" square sign				
Street: 4 lanes plus turning lane, north and south travel, 25 MPH, “sharrows” in one lane each direction				
	Number Pedestrians Per Crossing	Type of Eventual Crossing	Number Vehicles Passed Before Crossing	Near Conflict
	5	gap	5	
	1	gap	1	
	1	forced	1	
	2	gap	0	
	1	gap	3	
	1	gap	0	
	1	gap	0	
	2	forced	1	
	1	gap	0	
	1	forced	1	1
	1	forced	2	
	2	yield	1	
	2	gap	0	
	3	yield	7	
Total	**24**		**22**	

Table 2

Summary of High-Visibility Signage Midblock Crossing Location #1

Number of Pedestrians That Crossed:		
During Gap	14	58.33%
During Yield	5	20.83%
Forced Yield	5	20.83%

Number of Pedestrian Groups That Crossed:		
During Gap	8	57.14%
During Yield	2	14.29%
Forced Yield	4	28.57%

Vehicles that passed	22
Vehicles that yielded	2
Total vehicles	24
Yield Rate	**8.33%**

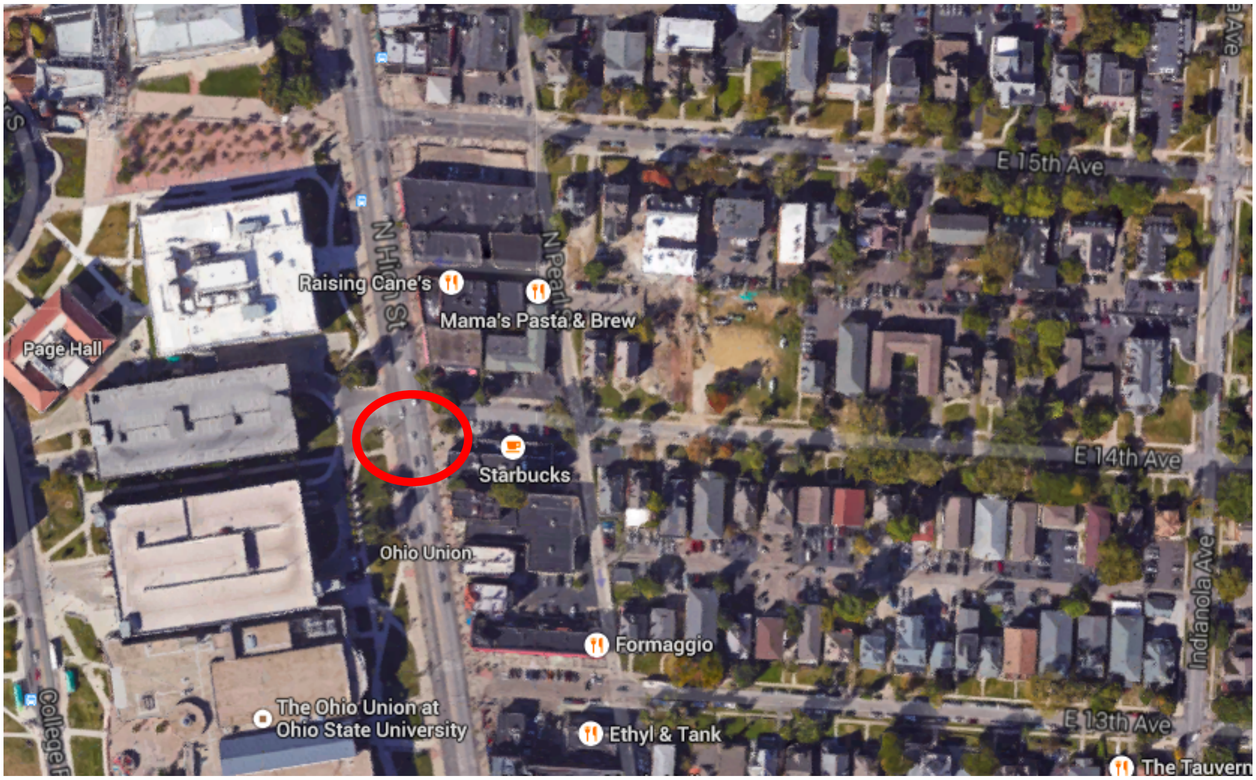
Two groups received yields. One of these two groups watched six vehicles pass while they were standing on the edge of the curb, visibly waiting to cross, before the 7th vehicle finally yielded for them. The other group had to wait for one passing vehicle before the 2nd vehicle yielded. No groups were yielded to by the first approaching vehicle. The overall yield rate for this location was 8.33%. There were 24 vehicles who had the opportunity to yield and only two did.

It may be worth noting that the two groups that were yielded to had two and three pedestrians crossing in each group, whereas three of the four groups that forced a yield consisted of only one pedestrian.

The pedestrian groups who crossed during gaps were routinely able to cross without waiting. All but three of the 14 groups crossing during a gap were able to proceed across the street immediately after arriving at the crosswalk. The other three groups (21.42% of gap crossing groups) had to wait for traffic to pass them and a gap to appear. This would indicate that traffic is not constant at this location and enough natural gaps occur for a pedestrian to cross on their own. It is important to note that the crossing observations were categorized by the type of crossing that occurred when the pedestrian first entered the crosswalk. This means that, even though a pedestrian crossed during an initial gap in traffic, by the time they reached the other side, they may have forced motorists to yield to them. Overall, qualitatively speaking, motorists seemed patient when forced to yield in this manner. Only a few created potential conflict environments by trying to speed past a crossing pedestrian group before the group could reach the motorist's current travel lane. That is how the one recorded conflict did occur.

High-Visibility Signage on High Street at 14th Avenue

The second study of a midblock crossing on High Street is located in the same environment, at about 14th Avenue, a few blocks south of the first location (Map 2). This crossing has a diamond shaped pedestrian high-visibility sign side-mounted at the crosswalk, similar to the previous crossing. As shown in Figure 2, however, this sign also has a small rectangular high-visibility sign below the diamond sign with an arrow pointing towards the crosswalk. There is again a "yield to pedestrians here" sign further upstream, pointing to a thick white line. The crosswalk is striped and visible. There is a row of triangles leading up to the crosswalk as well. These signs and pavement markings exist in both directions of travel.



Map 2: High Street, at about 14th Avenue across from Ohio State (Google Maps)

Figure 2: Crossing conditions on High Street south of Woodruff Avenue and at about 14th Avenue

Table 3 shows the observations from this crossing. Here, 33 pedestrian groups were recorded crossing, for a total of 47 pedestrians. The summary of this data is in Table 4. Of these 33 groups, 26 (78.79%) crossed during a gap, four (12.12%) received a yielded vehicle, and three (9.09%) forced a vehicle to yield to them. 10 (38.46%) of the 26 gap-crossing groups had to wait for a gap in traffic after arriving at the crosswalk. These waits ranged from one passing vehicle to 16.

Table 3

<u>Data from High-Visibility Signage Midblock Crossing Location #2</u>

Location: High Street, across from the Ohio Union parking Garage and Urban Outfitters, at about 14th Avenue

Design: Striped; (The following in each direction): Row of triangles painted on roadway approaching crosswalk, Diamond-shaped neon pedestrian sign with rectangular neon arrow and small square "yield to pedestrians in crosswalk" sign, "yield here to pedestrian" square sign

Street: 4 lanes plus turning lane, north and south travel, 25 MPH, "sharrows" in one lane each direction

	Number Pedestrians Per Crossing	Type of Eventual Crossing	Number Vehicles Passed Before Crossing	Near Conflict
	2	gap	0	
	1	gap	0	
	2	gap	0	
	1	yield	0	
	1	gap	0	
	1	gap	2	
	1	forced	1	1
	6	gap	0	
	2	gap	2	
	1	gap	0	
	2	gap	0	
	1	forced	1	
	1	gap	0	
	1	yield	0	
	1	forced	4	
	1	yield	0	

	1	gap	16	
	2	gap	0	
	1	gap	0	
	1	gap	1	
	2	yield	1	
	1	gap	3	
	1	gap	4	
	2	yield	1	1
	1	gap	0	
	2	gap	0	
	2	gap	0	
	1	gap	3	
	1	gap	0	
	1	gap	1	
	1	gap	0	
	1	gap	6	
	1	gap	2	
Total	47		48	2

Table 4

<u>Summary of High-Visibility Signage Midblock Crossing Location #2</u>

Number of Pedestrians That Crossed:		
During Gap	37	78.72%
During Yield	7	14.89%
Forced Yield	3	6.38%
	47	

Number of Pedestrian Groups That Crossed:		
During Gap	26	78.79%
During Yield	4	12.12%
Forced Yield	3	9.09%
	33	

Vehicles that passed	48
Vehicles that yielded	4
Total vehicles	52
Yield Rate	**7.69%**

The number of vehicles that passed before a yield occurred (when a yield occurred) were on average much lower than the previous crosswalk on High Street at 18th Avenue. In fact, all four groups had a vehicle yield to them after one or less passing vehicle. This is a quick yield rate for the yields that did occur. The yield groups were small, two or fewer pedestrians each.

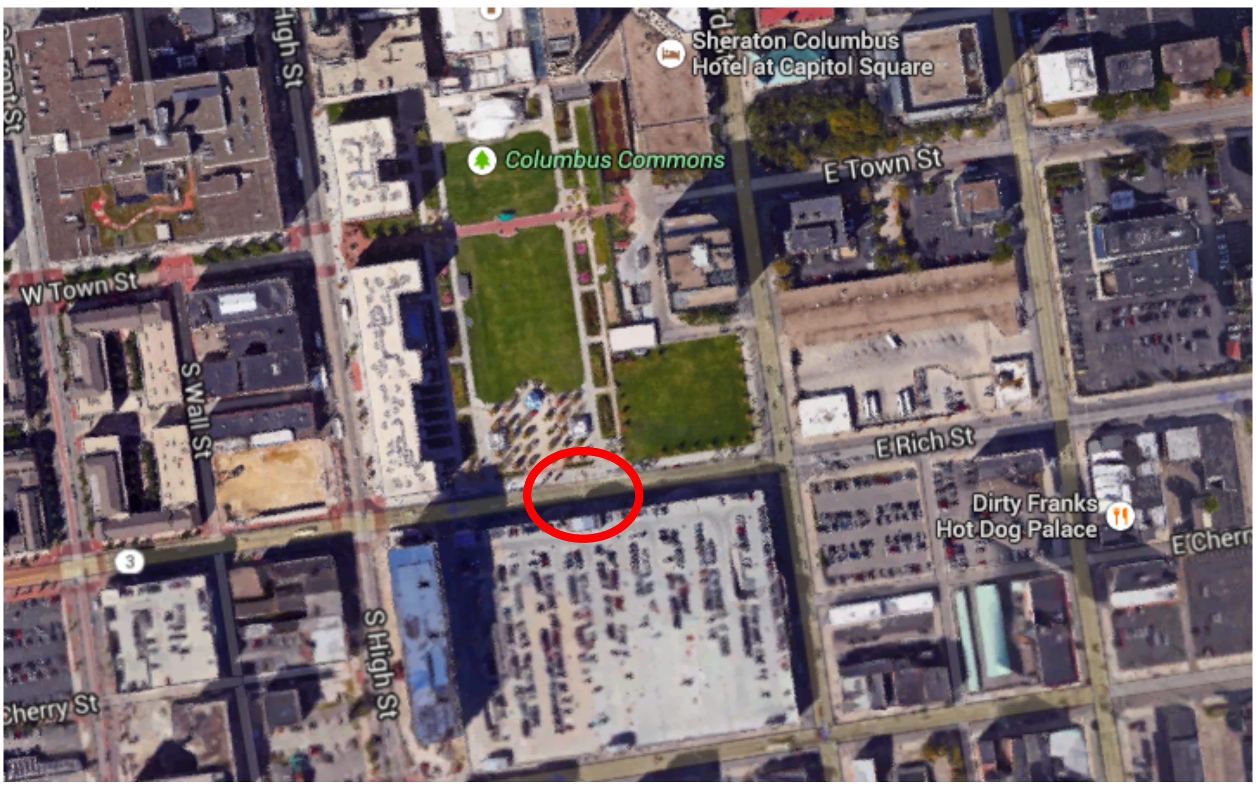
Again, the three groups that forced a vehicle to yield to them consisted of only one pedestrian. One of the two near conflicts occurred during one of these forced yields. The other occurred while the pedestrian group was crossing the far two lanes of traffic after being yielded to on their origin side. In this case, a vehicle sped up quickly in front of a group of crossing pedestrians in order to avoid yielding to them.

The overall yield rate for this location was 7.69%. This is found by taking the number of pedestrian groups who were eventually yielded to (four) divided by the number of vehicles who passed a waiting pedestrian group (52).

These crossings do not meet all of the criteria for “effective.” There were near conflicts, forced yields, and there did not appear to be a high level of visibility of waiting pedestrians. One hypothesis, in addition to faster speeds and a high number of lanes, is that the pedestrian is not positioned in a high-visibility location when waiting to cross due to the street design. Lane width, lane numbers, street-level crosswalk, and no signage in the street all likely contribute to this.

High-Visibility Signage on Rich Street Between 3rd Street and High Street

The next sign study at a midblock crossing occurred on Rich Street, in between 3rd Street and High Street in Downtown Columbus, Ohio (Map 3). This crossing is in between Columbus Commons, an outdoor event space, and the associated parking garage. This garage is used during the week for many downtown employees and professionals while the event space is used for a few hours a week. During the study, the event space was unused and functioned as an open green space. The street consists of three one-way lanes headed west. No posted speed limit was visible. The crosswalk is popularly used for crossing the street and heading into the garage. Signs posted at this location included the following: Diamond-shaped neon pedestrian sign with neon rectangular arrow on each side of street, "yield here to pedestrian" square sign each side of street, overhead diamond-shaped neon pedestrian sign. The crosswalk was striped and a row of triangles leading up to crosswalk was present (Figure 3). An important observation to make here is that, due to the one way nature of the road, both sides of the road displayed the same signs, which results in increased visibility of them by travel lanes.



Map 3: Rich Street, in between 3rd Street and High Street in Downtown Columbus, Ohio (Google Maps)

Figure 3: Crossing conditions on Rich Street, in between 3rd Street and High Street in Downtown Columbus, Ohio. The garage can be seen here on the left.

The results of this observation are shown in Table 5. A total of 148 pedestrians crossed here during the observational period, in a total of 62 groups. The majority of pedestrians were observed to be business professionals leaving work for the day. Of the 62 groups, 45 (72.58%) were yielded to and the remaining 17 (27.42%) crossed during a natural gap in traffic. Table 6 shows these results summarized. There were no forced yields and no near conflicts. Only five (8.06%) groups had to wait for a vehicle to pass before they were able to cross. None of the gap-crossing groups had to wait for any passing vehicles. The five groups that had to wait for a yielding vehicle only had to wait for one passing vehicle each before the next vehicle yielded to them. This results in a yield rate of 80.00%.

Table 5

Data from High-Visibility Midblock Signage Location #3				
Location: E Rich Street, between High Street and 3rd Street, across from Columbus Commons				
Design: Striped, Row of triangles leading up to crosswalk, Diamond-shaped neon pedestrian sign with neon rectangular arrow below on each side of street, White reflective "yield here to pedestrian" square sign each side of street, Overhead diamond-shaped neon pedestrian sign				
Street: 3 lanes of one-way western travel, no posted speed limit				
	Number of Pedestrians Per Crossing	Type of Eventual Crossing	Number of Vehicles Passed Before Crossing	Near Conflict
	4	yield	0	
	1	yield	1	
	1	yield	0	
	2	yield	0	
	3	yield	0	
	2	yield	0	
	2	yield	0	
	3	yield	0	
	3	yield	0	
	3	yield	0	
	1	yield	0	

	3	yield	1	
	1	yield	0	
	1	yield	0	
	1	yield	0	
	1	yield	1	
	2	yield	1	
	1	yield	0	
	3+1	yield	0	
	3	gap	0	
	5	gap	0	
	4	yield	0	
	1	yield	0	
	2	yield	0	
	1	yield	1	
	1	yield	0	
	1	gap	0	
	2	gap	0	
	2	gap	0	
	2	yield	0	
	1	yield	0	
	1	yield	0	

	2+1	yield	0	
	1+5	yield	0	
	1	yield	0	
	1	yield	0	
	5+1+2	yield	0	
	1+1	yield	0	
	1	yield	0	
	1	gap	0	
	1	gap	0	
	6	gap	0	
	2	yield	0	
	1	gap	0	
	2	yield	0	
	3	gap	0	
	1	gap	0	
	1	gap	0	
	4	yield	0	
	3	gap	0	
	1	gap	0	
	1	gap	0	
	4	yield	0	

	3	gap	0	
	3	yield	0	
	1	yield	0	
	2	gap	0	
	1	yield	0	
	1	yield	0	
	4+5+1+1	yield	0	
	1	yield	0	
	6+1	yield	0	
Total	148		5	0

Table 6
Summary of High-Visibility Signage Midblock Crossing Location #3

Number of Pedestrians That Crossed:		
During Gap	37	25.00%
During Yield	111	75.00%
Forced Yield	0	0.00%
	148	

Number of Groups That Crossed:		
During Gap	17	27.42%
During Yield	45	72.58%
Forced Yield	0	
	62	

Vehicles That Passed	5
Vehicles That Yielded	45

Total Vehicles	50
Yield Rate	**80.00%**

At this location, drivers were very willing to yield and displayed a high level of visibility. On approximately seven crossings, yielded drivers saw additional pedestrian(s) nearing the crosswalk and decided to wait for them to reach and allowed them time to cross, even after already yielding to a group. This did not occur once at the other crossing locations.

The observations here support the literature's findings that more lanes decrease the chance of yielding. The road on High Street had four travel lanes plus one turn lane, making it a fairly wide street. The three lanes on Rich Street make for a much narrower road and perhaps increase the yield rate. Motorists were also traveling at lower speeds on Rich Street, despite the lack of a posted speed limit. This may have also facilitated a higher yield rate, which would support the literature's findings that lower speeds result in higher yield rates.

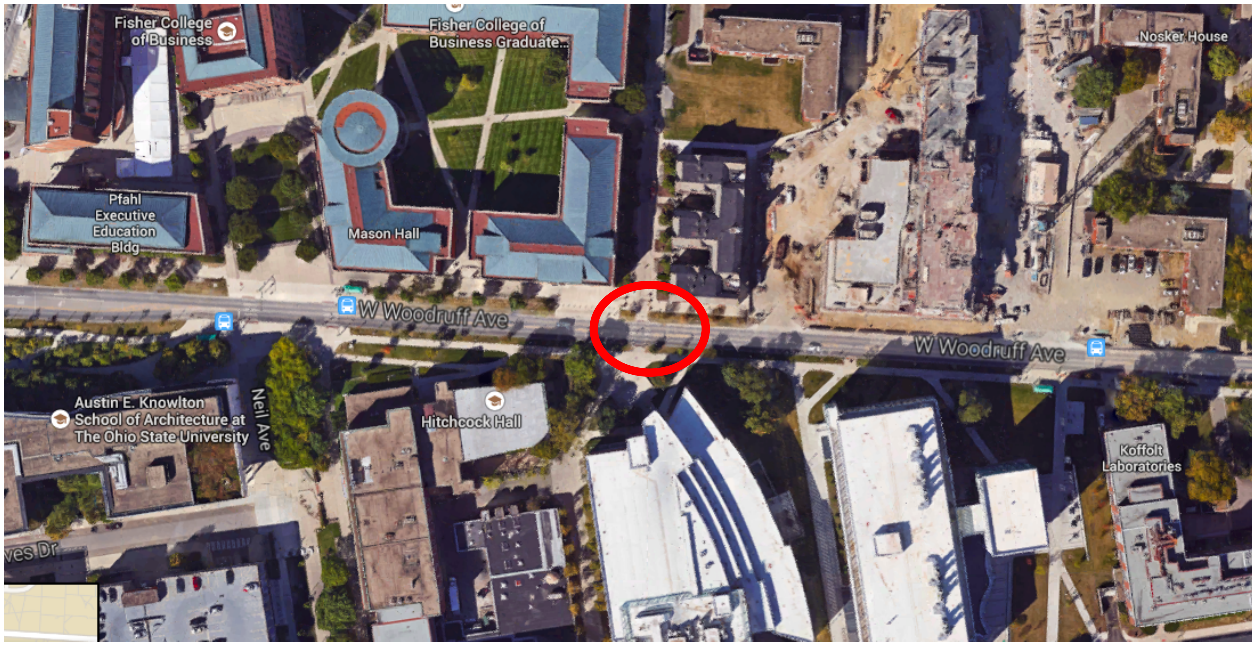
This paper also hypothesizes a few more reasons why the location at Rich Street may have found more vehicles willing to yield. First, the overhead signage increases visibility of a crosswalk that all lanes are able to see. The majority of drivers, regardless of travel lane, would likely be able to see the warning signage. This may have a positive impact on yield rate. I would expect to find an increased yield rate if overhead signage was introduced at the locations on High Street. Second, the one-way road creates an environment in which side-mounted signage can be seen by two of the three lanes rather than two of the five lanes as seen on High Street. A warning is useless if it is not visible or obstructed by fellow drivers' cars.

Finally, this paper hypothesizes that driver experiences may impact their likeliness to yield. Groups of same users relate to one another. In the current transportation culture in this city, pedestrians (as well as bicyclists and transit riders) are viewed as the less-than group by many drivers. At the Rich Street location, a large majority of pedestrians crossing the street turned into drivers a few minutes later. The parking garage exit fed into the same stream of traffic that crossed the crosswalk. Though not all traffic passing had come from the garage, drivers that had just been pedestrians on that same crosswalk are expected to be more aware of the pedestrian environment they were just a part of and thus more likely to yield, as they were yielded to. Additionally, even if a driver had not just crossed that crosswalk and come from the garage, they are at minimum subconsciously aware that many pedestrians are headed into the garage where they will also become drivers. And finally, the majority of pedestrians crossing at this location were clearly business professionals leaving work for the day, which is what the majority of the crossing drivers were also likely doing. The ability to empathize, even subconsciously, could be a powerful behavior modifier.

Overall, this crossing met the three criteria for “effective.” There were no near conflicts, there is high visibility of the pedestrian, and the yield rate is relatively high. Drivers were able to see approaching pedestrians from far away as was observed by their decision to wait for additional pedestrians to cross.

In-Street Signage on Woodruff Avenue

The final sign study conducted analyzed in-street signage. The location studied was on Woodruff Avenue in the Ohio State University, across from the Physics Research Building (Map 4). The road is a two lane, high pedestrian volume and high-moderate vehicle volume two way street. Pedestrian warning signs include a striped crosswalk with parallel striped lines leading up to crosswalk in each direction, diamond-shaped side-mounted neon pedestrian signs with downward arrows on each side, and an in-street “yield to pedestrian” sign in between the two lanes (Figure 4). The posted speed limit is 20 MPH.



Map 4: Woodruff Avenue in the Ohio State University, across from the Physics Research Building (Google Maps)

Figure 4: In-street sign crossing conditions on Woodruff Avenue in the Ohio State University, across from the Physics Research Building

Observations at this location can be found in Table 7. There was a total of 253 crossing pedestrians in a total of 52 groups. 12 (23.08%) groups crossed the street during a natural gap in traffic and the remaining 40 groups (76.92%) crossed during a yield. This summary can be found in Table 8. There were no near conflicts or forced yields. Pedestrian group sizes ranged from one to 17, the largest of any location. Often, drivers would wait for additional approaching pedestrians in the same manner that was observed on Rich Street.

Table 7

Data from In-Street Signage Midblock Crossing Location				
Location: Ohio State University, Woodruff Avenue Across from Physics Research Building				
Design: Striped crosswalk with perpendicular lines leading up to crosswalk in each direction, Diamond-shaped high-visibility pedestrian signs with arrows, In-street yield to pedestrian sign				
Street: 2 lanes in opposite direction, 20 MPH				
	Number Pedestrians Per Crossing	Type of Eventual Crossing	Number Vehicles Passed Before Crossing	Near Conflict
	6	gap	0	
	3	yield	0	
	1	gap	0	
	1	yield	0	
	1	gap	0	
	3	gap	0	
	1	gap	0	
	2	gap	0	
	1	gap	1	
	2	yield	0	
	5	yield	0	
	2	yield	0	

	6	gap	0	
	4	gap	0	
	1	gap	1	
	1	gap	0	
	8	yield	1	
	4	yield	0	
	3	yield	0	
	3	yield	0	
	3	yield	0	
	4	yield	0	
	3	yield	0	
	1	yield	1	
	3	yield	0	
	10	yield	0	
	1	yield	2	
	14	yield	0	
	3	yield	0	
	5	yield	0	
	3	yield	0	
	5	yield	0	
	1	gap	0	

	15	yield	0	
	11	yield	0	
	7	yield	2	
	6	yield	0	
	2	yield	0	
	7	yield	1	
	1	yield	1	
	7	yield	0	
	3	yield	0	
	17	yield	0	
	6	yield	0	
	8	yield	0	
	6	yield	0	
	6	yield	0	
	7	yield	0	
	7	yield	0	
	4	yield	0	
	14	yield	0	
	5	yield	0	
Total	253		10	0

Table 8
Summary of In-Street Signage Midblock Crossing Location

Number of Pedestrians That Crossed:		
During Gap	28	11.07%
During Yield	225	88.93%
Forced Yield	0	
	253	

Number of Groups That Crossed:		
During Yield	40	76.92%
During Gap	12	23.08%
Forced Yield	0	
	52	

Vehicles That Passed	10
Vehicles That Yielded	40
Total Vehicles	50
Yield Rate	**80.00%**

The yield rate calculated for this location was 80.00% (10 vehicles passed waiting pedestrians and 40 yielded to them). This is consistent with the literature findings of an average of 87% yield rate. Based on observations, I believe yielding rates would have been higher if the pedestrian volume was slightly less. Drivers appeared to get frustrated by the large amount of pedestrians crossing and holding them up. For the most part, every vehicle would take its turn yielding to a group of pedestrians, so that almost every other vehicle was yielding. Qualitatively speaking, however, the behavior appeared to indicate that some drivers simply did not want to wait any longer and were then unwilling to yield themselves.

It was a safe crossing environment, however. The in-street signage, combined with narrow lanes, slow speed, and the high visibility of pedestrians waiting caused this crossing to meet the three criteria for "effective:" there were no near conflicts, there is high visibility of the pedestrian, and the yield rate is relatively high.

Conclusions

In conjunction with the literature, we can see that number of lanes, the width of roadway, and speed matter. The slower streets and the narrower streets saw higher yield percentages, resulting in more effective crossings. Slower speeds and narrow streets facilitate slower vehicle travel, allowing drivers more time to become aware of pedestrians waiting to cross. These higher yield percentages meant that because drivers voluntarily yielded to a waiting pedestrian more often, fewer conflicts occurred and a safer environment was maintained.

As suggested by the literature, in-street signs may prove to be effective, resulting in safe crossing conditions and high yield rates. Another trend in the research done in this paper was that higher pedestrian volumes tended to see higher yield rates. This is consistent with what was observed at the crossings in this study. This is certainly the case here. Comparing the two crossings on High Street with the crossing on Rich Street, we can see a much higher yield rate and much higher pedestrian volume at Rich Street. In addition to higher yield rates, increased pedestrian volumes seemed to produce a safer crossing environment. No groups of more than 2 felt the need to force a yield in any scenario. This could be because a higher pedestrian presence demands more attention from a driver and begins to re-prioritize the street's users, causing drivers to feel obligated to yield. Or it could simply result in drivers becoming accustomed to yielding at particular locations, knowing the pedestrian presence is high.

Overhead signage and dual side-mounted signs contributed to a more effective crossing, as evidenced by the high yield percentage at the Rich Street location. The increased visibility of warning signs may benefit pedestrian safety. With overhead signage in particular, nearly all vehicles should have an unobstructed view of the pedestrian warning. This may translate to more drivers taking notice of and obeying the sign, resulting in greater awareness of a pedestrian presence and a greater probability of drivers yielding.

The two High Street locations, just four blocks apart, showed no difference in yield rates, despite the additional signage posted at the 14th Avenue location. At that location, an additional high-visibility arrow sign was posted below the diamond-shaped high-visibility pedestrian sign to indicate to vehicles where a pedestrian would cross. The observations, which were performed on the same day, indicated no discernable difference in either driver awareness or driver yield rate.

Finally, it is expected that driver experiences and their ability to relate to other road users may help influence their behaviors, as was observed as a possibility on Rich Street. It is likely that a driver who had just acted as a pedestrian would be more apt to be aware of and yield to a pedestrian in the near or immediate future, resulting a safer street.

Limitations and Recommendations for Future Work

This research has shortcomings and limitations which yield to future studies. First, the two High Street locations were quite similar in design and it may be beneficial to observe the same high-visibility signage effectiveness along a roadway with different characteristics to determine where it may be most successful. It is important to determine the impact that each location's individual characteristics have on driver yield rate. For example, the same high-visibility signage found at High Street may be more effective along a roadway with fewer lanes, narrower lanes, or a lower speed limit. Differentiating the impact of each roadway element will help determine the most appropriate way to utilize each tool.

It would be advantageous to study another location where overhead warning signage exists, but in an environment without a high pedestrian-to-driver turnover rate. Separating this variable would allow for additional study of overhead signage and its impact on driver yield rates without the additional influence of a recent experience as a pedestrian. Additionally, a separate study analyzing the impact of driver experiences on yielding behavior would be necessary to address this hypothesis. This analysis could differentiate the impact of experience on driver behavior from the impact of signage. For example, a driver who had just recently acted as a crossing pedestrian may be more willing to yield to or more aware of pedestrians crossing in the same place, regardless of available signage. If this is the case, planners could choose to apply this in street designs to improve pedestrian safety.

In future work, I would also like to separate the overhead signage variable from the one-way street variable to see the effects each of these may have on driver yield rate. As Walker, Kulash, and McHugh point out, one-way streets typically give way to a higher vehicle speed and decreased safety for pedestrian users. This is contrary to the environment observed at the Rich Street crossing location, so it would be useful to observe an additional variety of combinations of one-way and two-way streets and high-visibility signage, in-street signs, and overhead options.

Finally, studying the in-street signage in a non-university setting with less pedestrian traffic may be beneficial in understanding the limitation of this method. Though it received a very high yield rate consistent with the literature, a control may be necessary to determine if pedestrian volume or in-street signage had the biggest effect here.

Walking is an important mode of transportation throughout our communities. Pedestrian travel is also increasingly becoming a more convenient and desirable mode of travel as cities work improve walkablility, health, and equity. Midblock crossings must be utilized in order to contribute to this convenience as they encourage pedestrians to cross legally. An important part of ensuring a successful and walkable community is safety. The pedestrian awareness/warning methods studied at midblock crossings in this paper can all be effective elements towards increased safety. These signals, signs, and pavement markings each have environments in which they are most effectively leveraged to alert drivers to pedestrians. Along with narrower road widths, slower speeds, and fewer lanes, these elements can help planners and engineers increase pedestrian crossing safety and install effective midblock crossings.

Wayfinding Signage Considerations in International Airports

Abstract
Airports are complex spaces that exist primarily for the purpose of allowing significant numbers of people to fly from and into, a specific location. In these spaces, wayfinding is an important process, given that these people need to be moved in a time effective and safe manner, to various locations within the airport. In addition to the use of space, human help, and electronic technologies, static signage is an important tool in guiding people in airports. In this study I focus on static signage as a wayfinding tool in airports and I report on the findings from three wayfinding audits that this author did in three UK international airports in the last year.

Keywords: wayfinding, signage, airport wayfinding, human factors

Introduction
Trying to guide users to and through an airport is a particularly complex activity, especially around some of the large international airports, some of which might be thought of as mini-cities. In 2015, for example, over 100 million passengers flew in or out of Hartsfield–Jackson Atlanta International Airport in the U.S. (ACI, 2016), whilst in the UK, almost 75 million passengers used London Heathrow (ibid). It is not only though passenger who must be guided through airports, but also staff, airline crew (many of whom may be new to the airport), service providers, delivery drivers and so on. Moreover, users from many countries and cultures with varying mother tongues, and of varying abilities need to navigate these spaces. Signage in these airports, for example, needs to be legible for those with a range of visual abilities including those who are visually impaired. Indeed, travellers who suffer from some form of vision impairment, "have a condition that affects the function of their bodies but it is the disabling nature of socially constructed barriers that transforms them into a person with disability" (Small *et al*, 2012: 942). In this respect, a signage system that is not designed effectively to cater to those with a disability such as a sight problems, further alienates such passengers. Gottdiener (2000: 77) perhaps perfectly highlights the need for a good signage system, commenting that "inadequate sign systems result in passenger delays, perhaps missed planes which back passengers up; increased cost of travel; and the need for more personnel to help in a disorientating airport".

Planning a signage system in an airport is a complex and difficult practice, and this is further complicated by the way in which wayfinding is also a "heuristic" activity (Symonds *et al*, 2017: 4.3). Likewise, having checked-in and with no rush to navigate to and through the security areas, a passenger might look for a restroom (toilet), a shop to buy a gift, or a restaurant to find a bite to eat. Signage thus needs not only to guide passengers through and between the key areas of an airport, but needs to be designed such that users can also find their way for micro processes within the overall macro route. The meshwork concept (Ingold, 2011; Symonds *et al,* 2017) is useful in expressing these processes that wayfinding signage needs to accommodate, the meshwork much like a fishing net of divergent paths that meet at certain points (locations where multiple people's bodies meet and cross and move past and by each other). The meshwork represents a set of routes that evolve and are "lived" (Ingold, 2011: 151) rather than being static paths and routes. An effective signage system thus needs to guide people on direct paths but also to provide for these heuristic wayfinding needs that clearly exist as we move through airports. In most airports, there are four key areas in respect of wayfinding and these are the need to: i) find the airport itself and parking or main arrival points, ii) find the check-in/terminal, iii) navigate through airport and through security, and iv) to the departure gate.

Before proceeding to explain the methodology and then the findings, it is first worth providing a definition of wayfinding. The concept of wayfinding has existed for over a century but was first used as a one word term by Lynch (1960). Since Lynch, a number of definitions have been used in wayfinding literature but the one I use in this paper is from Symonds *et al* (2017: 4.12) who classify wayfinding as "the cognitive, social and corporeal process and experience of locating, following or discovering a route through and to a given space". Even though wayfinding can be a largely sociocultural process through acts such as people asking, in this paper, I focus on physical signage, drawing on the experiences from auditing three UK airports. I avoid too much focus, in this specific paper, on the design of space and other non-signage wayfinding techniques, in order to focus on physical signage. In the section that follows, the methodology used is explained.

Methodology

In 2016, as a consultant whilst completing a PhD in wayfinding, I carried out wayfinding audits for three U.K airports and these were Birmingham International (BHX), Cardiff International (CWL) and London Gatwick (LGW). A total of six visits were made to the airports and permission was given for photographs to be taken and feedback was provided to each airport. No passengers were interviewed on these specific audits.

The findings in this paper are qualitative in nature, justified in that the audits and findings provide an "exploratory" (Silverman, 2013) form of research and on which quantitative research could be based on in the future, if deemed necessary. Qualitative research of this type provides a useful way of discovering underlying issues (Lo Iacono *et al, 2016*: 2.2) that might not otherwise be discovered in quantitative research. In the section that follows, some of the main issues and solutions in respect of signage are discussed.

Findings and Discussion

Introduction to the Complexities of Signage and Stakeholders

Before explaining the various types of signage and related issues, it is worth briefly drawing on Bourdieu's (1977) theory of practice in order to portray the complexities of signage in airports. Bourdieu's concept of field, applied to a given space or environment, allows us to see such space as a social (and not just physical) field with the competing forces (constituted by social actors) acting within and upon that space. Without delving too deeply in this paper into the theory, and various forms of capital and habitus that influence "the field", Bourdieu's comparison of social actors competing in a social field to increase their capital, to players competing in a sport field, help us visualise the way in which various stakeholders shape the process of wayfinding in airports. Airports, when planning a signage system, are influenced by numerous stakeholders in the practice, and these stakeholders all help to shape and ultimately guide the signage design process. These stakeholders include:

- *Institutions:* such as the government and hence the need to provide regulatory signage and, as it will be discussed below, multi-language signage aimed to push governmental decisions over the protection of a local language.
- *Commercial outlets:* who want to make their store fronts or service visible.
- *Service providers:* such as limousine and taxi-cab drivers who need to be able to find their way (not easy in an airport such as JFK in New York, U.S.)
- *Passengers:* who need to be able to find their way not only to the airport, but through it and this needs to include for small processes such as finding the special assistance desk. Connecting passengers also need to be considered and time is often a precious resource for these passengers.
- *Airport owners:* different rules exist in each country, regards airport ownership. In the Unites States, for example, airports tend to be state owned whereas airports in the UK are independent ventures and this has a direct impact on the commercialisation of an airport and, in turn, it impacts on the commercial signage in the UK airports.

Signage Types

The signage, in the three airports studied, can be broken down into five distinct types and these are i) directional, ii) identifying, iii) informational, iv) regulatory and v) commercial. Certain signs inevitably fit into two or more of these categories but the key point to understand is the various forms of signage required to fully accommodate a positive user experience (UX) and to keep users safe, in an airport environment.

Figure 1 - Example of Directional signage

Figure 2 – Identifying signage example - in the image above, the numbered signage acts to confirm the location of carousel 6

Figure 3 - Example of informational signage

Figure 4 - Regulatory signage

Figure 5 - Commercial signage example

Common Signage Problems in Airports Found and Solutions

In the three airport audits, certain issues were experienced and in this section I will explain some of the most common issues seen and suggest examples of solutions.

Multi Language

Although not a problem as such in most American airports, consideration for the local language spoken in the country of the airport and the language spoken by a large number or even majority of passengers, creates a real dilemma for those planning the signage system and for the airport implementing the signage. Despite less than 12% of the residents of the Welsh capital Cardiff being able to speak Welsh (BBC, 2012), the airport is under immense pressure from the Welsh Assembly (government) to ensure that Welsh is included on all signage in the airport (Cardiff Airport, n. d.). Signage planning, in other words, can involve politically motivated decisions based on issues such as heritage.

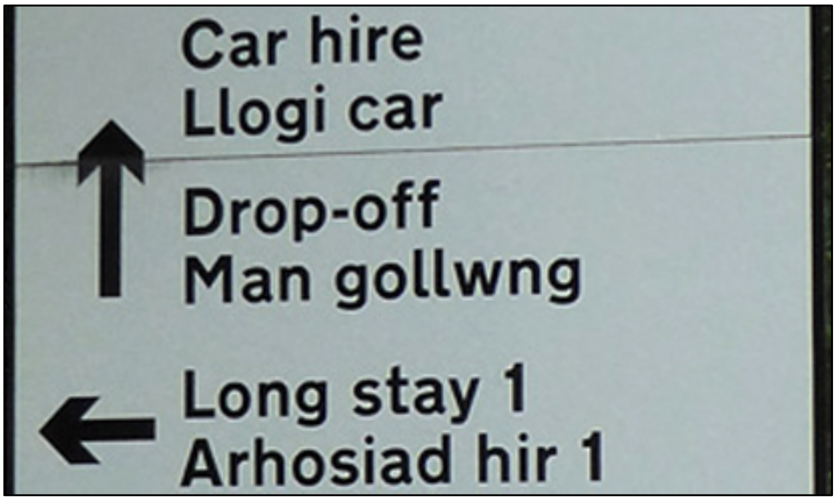


Figure 6 - Multi-lingual signs. An example of poor design.

There are a number of solutions for successfully including more than one language on signage. The use of colour coding, to make it clear to the passenger which text to focus on, can be particularly helpful, especially in the case where passengers are driving into an airport and have little time to make decisions. This was a particular problem in Cardiff Airport and certainly a reason for difficulties for passengers. Having one language in a different font size and separating each section of text with a line between each section was also suggested. Another option can be to make use, where possible, of icons that are globally recognised, rather than to use two languages. Toilet (restroom) signage can be created in this way to overcome linguistic issues. As Arthur and Passini (2002: 151) state, “the challenge of producing good signage is made more difficult by the fact that many people have reading problems that range from just poor reading habits up to not being able to read at all". Indeed, multi-language signage which does not differentiate the language by colour creates difficulties for readers.

Inconsistency with a Font and Design Family

Fewings (2001: 181) also makes an important point, stating that "signs should convey facts without ambiguity and at the time and place such facts are required. Signs should also direct, inform, control and identify, and it should be possible to distinguish between directional, identification and reassurance types of signs". These ambiguities that Fewings speaks of were a particular problem in two of the airports I audited and the reasons soon become clear. When talking with the airport management teams in the audit process, it become clear that a large number of signage suppliers end up being used for the airports. This results in a complete mismatch of signage in terms of a lack of standardised set of family fonts and design standards. As some airports develop, so do the number of suppliers and range of signage types. As signage experts, re-enforcing the need to try and bring all signage under one family and to create a standardised set of signs is needed. In order to try and create a more seamless signage system, involving as many of the key managers as possible, provides the greatest chance of ensuring that standardisation is brought to the airport as a whole.

Another problem experienced though that evolved from discussions with key personnel, is the understandable issue of costs and scope. A practical solution for developing a signage system for large airports and one preferred by those I talked with, was a multi-stage approach with specific parts of the airport planned for one at a time in respect of planning for signage. The cost of creating or replacing signage for all parts of an airport at once can be unrealistic. Hence, breaking down the process into manageable parts whilst first creating a standard plan that can be utilised airport wide, is suggested.

Clustering

Given the different forms of signage that exist in an airport setting (as mentioned earlier), "clustering" (Symonds, 2013) is an issue that needs to be avoided as various signs (signs that are sometimes put up by different departments within the same airport) begin to compete spatially with each other. The need to make airports profitable, particularly in countries such as the UK where airports are not state controlled, can be seen in some airports to result in commercial signage sometimes over-powering and effectively hiding or blocking directional wayfinding signage. The solution to avoid clustering is to create specific areas for each signage type. Advertising signage, for example, should not be placed alongside directional signage. Clear grouped areas for signage should be planned and site-lines for directional signage also need to be maintained.

Figure 7 - Competing signage

Design Inconsistencies and Errors

Figure 8 - Common signage errors

Auditing the three airports, inconsistencies in basic signage design standards and conventions were noticed in every airport. Such issues are common and the one sign above in Figure 8 highlights three obvious problems. Firstly, it shows a lack of consideration to the natural groups of texts in the sign. "Toilets" (Restrooms in American) should, for example, be grouped above or below "Baby Changing". Locations that are logically connected should be grouped in signage to make it easier for users to cognitively use signage more easily and naturally. Secondly, for best practice, arrows should always point away from text and towards the direction of the item they are pointing to, making it easier for users to distinguish the direction they need to take, rather than text pointing into text. Thirdly, inconsistency exists in respect of language with a mix of British English (such as "toilets" and "cash machine") and American English ("ATM"). Although such points might seem somewhat pedantic, such issues, when magnified by thousands of signs in a large airport, mean that wayfinding becomes more problematic.

Understanding the User Types

Not fully understanding the needs of all user types for a given airport is an issue that can be avoided relatively easily and yet proved to be problematic. What became apparent was that not all users will take the same routes in the way that one might at first expect. One particular example stands out from my interviews in my own PhD research on wayfinding. A disabled traveller, whom I will refer to as Mary for reasons of anonymity (in line with research ethics guidelines for the PhD), for example, rather than looking for the check-in area when arriving at an airport terminal, normally needs to find the "Special Assistance".

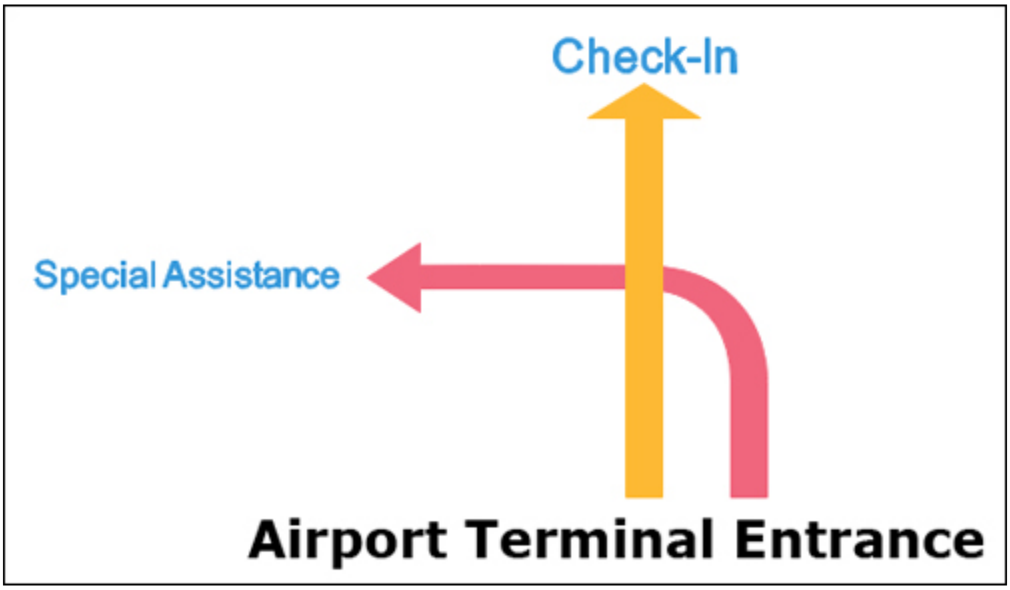


Figure 9 - Example route that may be needed for disabled passengers with check-in the second rather than first destination when entering a terminal.

While this is not an issue with the design of the signs themselves, the issue that exists is in being able to fully understand the routes and paths that need to be signposted in the first place. From the experiences of spending much time in three airport terminals and dressed in shirt and tie and with an airport visitor I.D around my neck, what was both surprising and interesting was the frequency with which passengers would approach me to ask the directions. Literally every minute or so, I would be asked for directions and, quite often, it was the same gate that passengers were having problems to identify the directions for. On further investigation, by looking for the directions myself, it soon became clear that one particular gate was an abyss in respect of the ability to find any directional information for that specific gate. The lesson here, for signage companies looking to create the best possible signage system in such an environment, is to spend even a very small budget just to gather some feedback from the very users who are likely to use the signage system in question. Moreover, the most knowledgeable people from the experiences of doing the audits proved to be, apart from the passengers, the front line service staff who get asked the same questions day in day out, including regards to specific locations. Making assumptions when designing a signage system often proves to be the reason for many poorly designed and ineffectively systems.

The range of user types also extends to division between those who are "familiar" and "unfamiliar" (Kellaris and Machleit, 2016: 5; Prestopnik and Roskos–Ewoldsen, 2000: 178). In addition to various levels of familiarity, effective signage in airports needs to accommodate a number of factors and these include a range of "ages", "motivations" and "internal states" as represented by Kellaris and Machleit (2016: 5) in their "Conceptual Framework for Signage Communication". By "internal states", Kellaris and Machleit (2016) and also Symonds *et al* (2017) refer to the emotional states and embodied effects that can affect the way in which a user will interpret signage and how the wayfinding takes place. Indeed, herein lies the importance of signage in the form of "confirmational signage", signs that provide confirmation and put a user's mind at rest. In airports long walks to a departure gate, even when the route is a direct one and users cannot take a wrong turn, they can still benefit from signage placed every so often to confirm the distance in terms of time or physical distance to the destination.

Figure 10 - Making use of confirmational signage

Wayfinding as an emotional experience can be increasingly so for those who are in need of "Special Assistance". As Small *et al* (2012: 942) posit, the "bodily experience of tourism is likely to be very different for the able bodied tourist and the tourist who is disabled". Signage can be used as an effective tool in order to help alleviate the cognitive stresses that such travellers experience, through the use of confirmational signs for providing information that acts as a source of comfort. Figure 11, below, shows another example of signage used to relieve passengers anxiety, in this case for those who are in need of special assistance, and who can often find using airports more traumatic than other passengers.

Figure 11 - Using signage to re-assure users about the route.

What Kellaris and Machleit (2016: 5) refer to as “motivational predispositions”, meaning the “extent to which people enjoy and regularly engage in the process of thinking” is an especially important consideration in locations in which signage is being used by a high percentage of holidaymakers or tourists. In certain situations, such as when we travel for vacation purposes, we can be in a heightened emotional state (we are excited for example) and we can thus become what Culler (1988: 1) rather interestingly describes as “droves, herds, swarms or flocks; they are as mindless and docile as sheep but as annoying as a plague of insects when they descend upon a spot they have discovered". Although a somewhat cynical way of explaining the habits of tourist, Culler makes an important point in that on vacation, and in other situations that can be emotive, there is a need to ensure that the signage system that is designed for such users, needs to factor in the difference in moods that we may experience in non-quotidian situations. In an airport, for example, the normally fast thinking and ever alert business wo/man, might be a passive and somewhat relaxed and unthinking traveller, as they relax, enjoy a drink in the airport bar and focus on their holiday. This is a journey, in other words, for unwinding and to be an unthinking individual and to enjoy being a sheep. One solution, in recent years, to cater for all emotive states, ages and abilities, has been a drive towards less but very large, high and bold signage, in the UK.

Figure 12 - Highly placed and very large unmissable signage.

Understanding the Embodied Wayfinding Experience and Signage Systems Design

Understanding wayfinding as a fully embodied experience also helps to shape the understanding of how signage systems can best be developed. In Figure 13 below, a model for wayfinding as an embodied experience is presented, taken from Symonds *et al* (2017: 4.1). Originally inspired by the model created by Lo Iacono and Brown (2016) to present intangible cultural heritage, the model presents the concept of wayfinding as a fully embodied experience that includes the cognitive and sociocultural.

Signage is presented under the heading “environment & artefacts”. The diagram is useful for expressing the places and socially active environments in which signage needs to be effective. By understanding wayfinding as an embodied activity rather than a cognitive only one, many of the mistakes that can occur in signage systems design can be avoided. Signage design that ignored the emotions, for example, (as earlier discussed) that inevitably exist when we wayfind and as also discussed by Kellaris and Machleit (2016) need to be factored into signage planning. There is the opportunity to avoid some of the mistakes that can otherwise exist in wayfinding research.

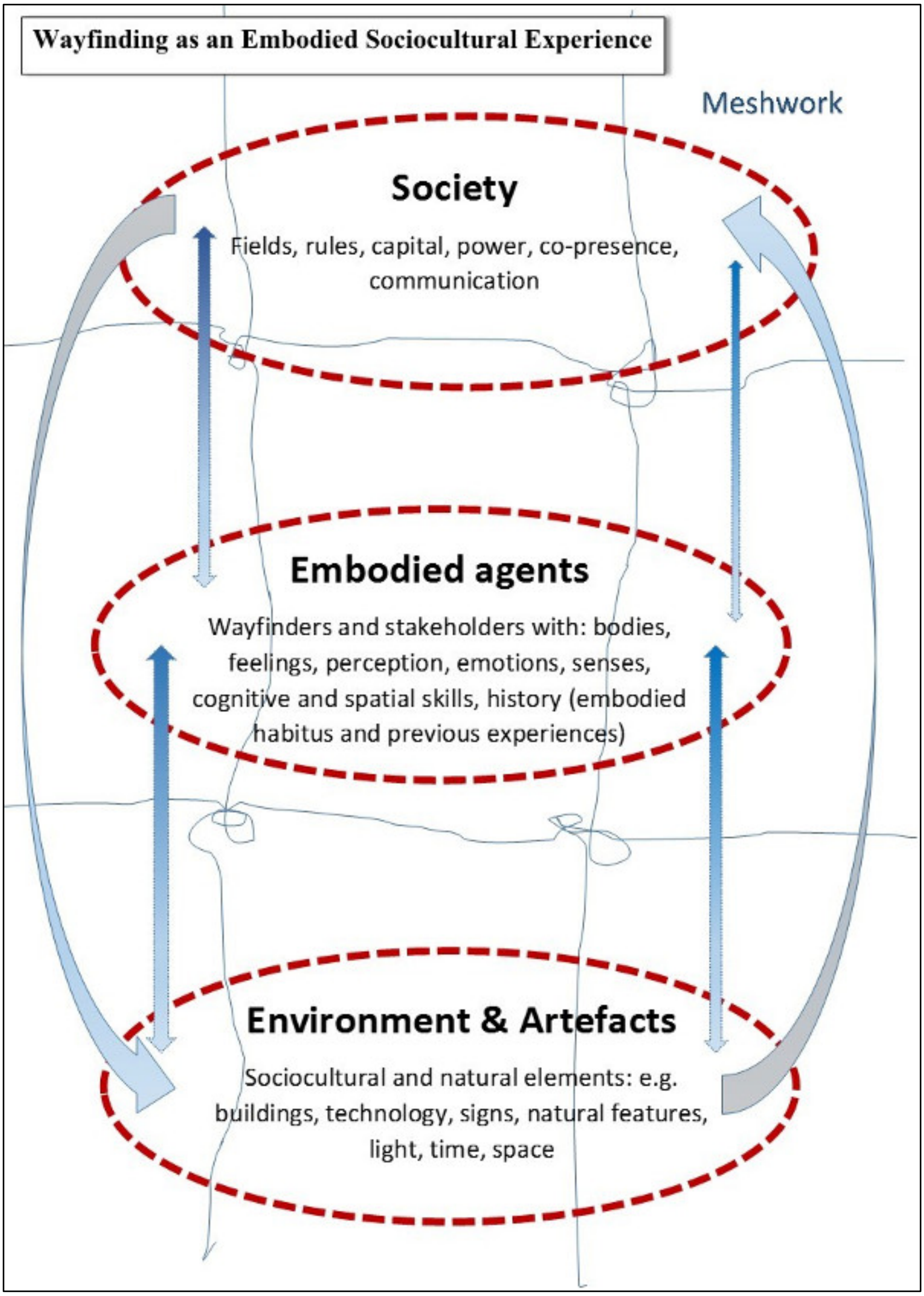


Figure 13 - Taken from Symonds et al (2017: par. 4.1) where a full explanation of the diagram can also be found.

To provide an example in airports, floor signage in the form of coloured lines that can be followed (Vilar *et al*, 2012: 4), such as to the train station serving an airport, can be extremely effective. Tested by virtual means as many wayfinding studies have tended to do (see Cubukcu, 2003; Emo, 2012 for example), the results would likely be that the floor lines work very effectively.

Figure 14 - Floor signage

When applied to an embodied wayfinding test, the results though can prove to be very different! The presence of numerous other bodies, for example, using the same physical spaces means that these lines can become hard to see, and also difficult to follow because other people block the way. Moreover, during the perambulatory process, the wear and tear of shoes and heels on the floor lines can quickly cause the lines to become eroded. In analysing wayfinding as an embodied process, greater understanding can be brought to signage design with the cognitive and corporeal seen as one under the term embodiment.

In real-world [1]wayfinding, certain features and thought-processes in signage design have long existed that factor in sociocultural needs. As shown in the image below in Figure 15 for example, from Gatwick Airport (London), consideration throughout the airport is given to height and signage placement. Placed at face height, such signage may be impossible to see in crowded environments. In order to overcome the resulting issue from placing signs so high, consideration has then been given to ensuring that the signs use

[1] "Real world" is used to refer to the lived physical world in which we live, as opposed to the virtual world.

very large fonts and with the text written on contrasting colours (in this case yellow on black). Consideration is also given throughout the airport to background lighting,

Figure 15 - Very high signage.

Use of Colour Differentiation and for Signage Grouping

Another useful technique used in the airports audited, is that of using colour for setting standards for signage types. Any signs relating to emergencies, for example, were always green in the three airports studied (see Figure 16 below).

Figure 16 - Emergency signage

Likewise, the colour yellow is used throughout the airport to represent toilets (restrooms) and is thus used to re-inforce signage in the form of text and symbols. Indeed, the use of colour is common as a way of re-enforcing signage. Read (2003: 235), in talking of child care environments, explains how colour can be used to guide people to their destination, whilst Sheehan *et al* (2006: 279), explain how those with special needs, such as dementia sufferers, have also been shown to be able to find their way easier, when colour is also used in partnership with signage as a tool.

Figure 17 - Gatwick Airport, London, and the use of colour Differentiation.

Temporary Signage

Another issue that became very apparent in all three airports was the extent to which temporary signage can be an issue. In very large international airports such as Gatwick Airport, some part of the airport is always being re-developed or changed, and signage and wayfinding is very often central to this process. In this respect, the point that Ingold (2011: 148-149) makes that wayfinding (and wayfaring) are like life itself, resonates here. Wayfinding is never a precise science, in that two people will never ever take precisely the same route using the exact same movements and signage needs ultimately to accommodate life-like movements, i.e. accommodate human factors. Like the heuristic and life-like movements for which signage must be developed for, the signage systems and spaces themselves also evolve and thus embody change and movement much like the people these spaces and signs work for.

In airports, temporary signage can be needed for a variety of reasons, such as because of terminal re-design, the change in airlines and their check-in desk location, expansion, or simply for repair work. Repairing wayfinding signage in the largest of airports, it should be remembered, is in an ongoing task. In one of the airports audited, the temporary signage was confusing and, on briefly observing passengers, it was clear that they were getting confused in terms of directions. There are two key issues when creating temporary signage in airports that I experienced. Firstly, the temporary signage did not match the font family and design specifications of the main signage system. Whilst this is understandable in that it is only temporary, I would argue that larger airports should be able to brand temporary signage and maintain a signage family (same fonts, designs and colours etc). Secondly, temporary signage, from my experience from these audits and from other audits, so often sends people in the wrong direction and unnecessarily creates a bad experience for passengers. Too little effort, in other words, is often allocated to temporary signage installation and design, and in large airports, where changes are continually being made, this can generate negative user experience (UX).

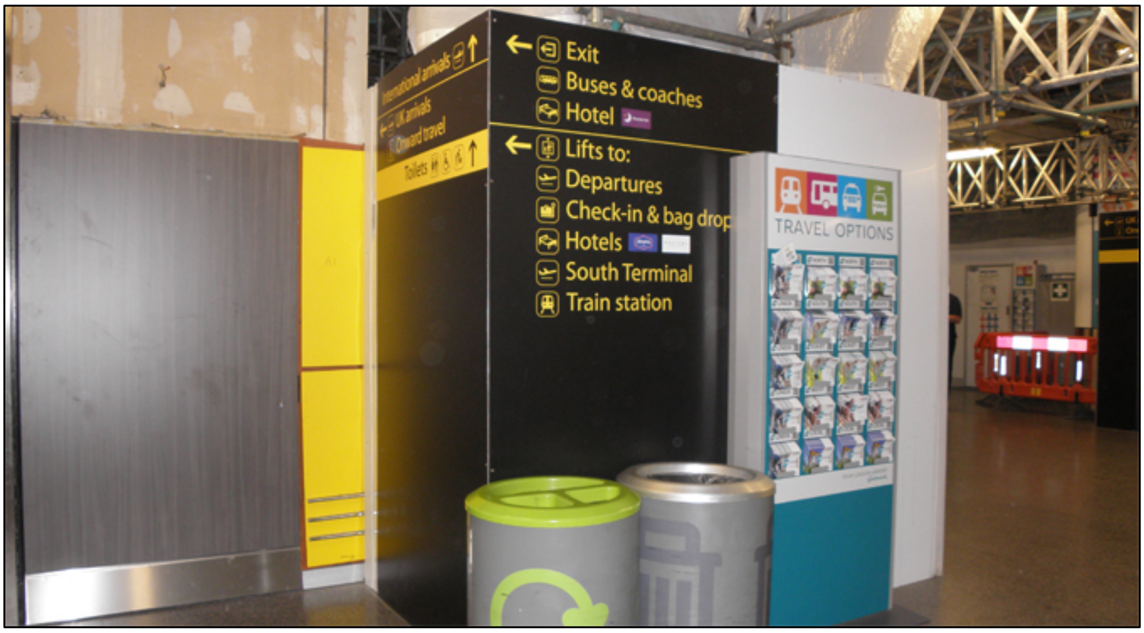


Figure 18 - Gatwick have a significant wayfinding budget and do go to great lengths also to present branded temporary signage.

Other Signage Considerations

Free-standing signage wrongly positioned – The key to managing a large signage system in a large airport is to create a wayfinding audit list and to do regular checks, i.e. weekly or monthly. In doing such checks, one problem that can easily be corrected and that occurs, such as because cleaners have moved them to clean underneath them, is free standing signage. In the audit, several signs in Birmingham Airport, UK, were facing the wrong way and would send passengers in the wrong direction.

Figure 19 - Free-standing signage facing the wrong way.

In highlighting many of the problems found, it is worth also noting that many things are done very well in the airports audited! The correct use, for example, of signage hierarchy was used in all three airports. By *signage hierarchy* this refers to the need to only include direct needs on signage. On arriving into an airport, for example, it is not necessary to sign for specific departure gates because it is too early in the decision making process. In such a case, directing users to the correct terminal (if there is more than one terminal) or towards the correct parking area is necessary. In all airports studied, signage system hierarchies were very well developed.

Conclusions and Recommendations

In this paper, I have presented a range of findings and observations from three wayfinding audits that I did in the UK in the last year. One of the key points to be made is that wayfinding signage systems in very large locations (such as in an international airport) need to be seen as organic systems and proper documentation and continual re-auditing of the signage system needs to exist. Furthermore, where possible, the signage system should use a signage family (i.e. fonts, styles, colours) and a seamless approach should be taken to ensuring that all areas of the airport integrate effectively.

It was also explained that most wayfinding work on signage systems in airports tends to be adapted rather than newly created. The reality of many airports is that they start off small and develop according to route development, resulting increase in passenger numbers and because of other factors. In order to try and maintain a standard structure in a large airport, despite the influence of a number of managers in different areas and aspect of a large airport, the key is to having an airport wayfinding signage plan where possible.

Rather than only seeing wayfinding as a cognitive practice, by seeing and analysing wayfinding as a fully embodied process, we can understand how multiple bodies, using the same signage system, can complement and aggravate each other's experiential use of the signage system. Airport signage systems need to consider human factors also, such as how signage may move because of quite simple issues such as because of cleaners moving free –standing signage. Many airports have no system in place to check such easy to fix issues and have no standard procedure in place to do signage checks on a regular basis.

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About the Author

Paul Symonds is completing a PhD in wayfinding and runs www.symondsresearch.com. He presently lives in Cardiff, UK, but has previously lived in USA, Korea, Spain and Ireland. Paul's research interests are wayfinding, research methods, embodiment and sociology.

Accessible Wayfinding : Empathy, human-centered design, and a blank slate.

ABSTRACT

Wayfinding and signage are important components of a building's structure and interior space for visitors with and without a mobile/physical disability, especially on university and college campuses. This paper documents a semester-long project where students in an upper-level design elective course identified a building on campus that had an inconsistent and missing wayfinding system. Documenting their ethnographic research and empathetic experiences, students were able to develop a wayfinding system based on research that focused on individuals with a mobile or physical disability. They produced and installed the system in the fall semester of 2016.

Keywords: wayfinding, graphic design, accessibility, disability, university

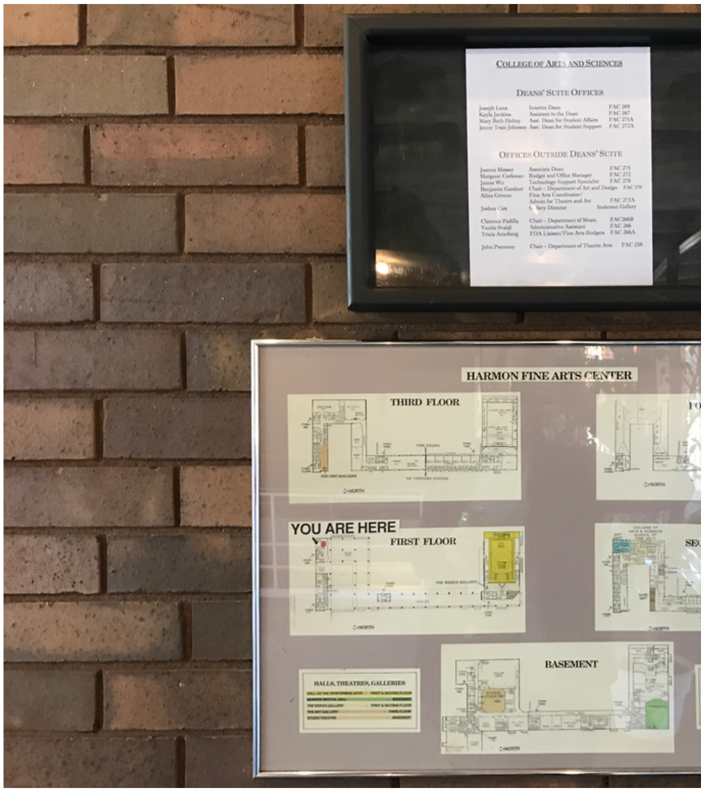
INTRODUCTION

The Society for Experiential Graphic Design defines wayfinding as information systems that guide people through a physical environment and enhance their understanding and experience of the space (Roux 2014). These systems are important components of a building's structure and interior space, especially on university and college campuses.

When they are missing, incomplete, or inconsistent those who enter the building are left confused and frustrated as they attempt to navigate the space. These feelings are intensified when a physical or mobile disability necessitates an alternative path.

Case in point, Drake University's Harmon Fine Arts Center (FAC). The 130,000sq foot, four-story building was constructed between 1970-72 by Harry Weese & Associates and opened to the public in the Fall of 1972 (Goodwin 1970). The Fine Arts Center currently houses the Music Department, Theatre Arts Department, Department of Art and Design, College of Arts & Sciences Deans' office, three performance theatres, Anderson Art Gallery, College of Arts &

Sciences Office of Professional & Career Development, Department Chair offices, and classrooms.



(*Figure 1. Wayfinding system in The Harmon Fine Arts Center.*)

Visitors are welcomed by the current wayfinding system (Figure 1) and as they navigate through the building they find signage on printed sheets of paper and room number placards on doors. Visitors are also expected to make use of the universal knowledge that room numbers coordinate with floor numbers (ex. room 205 is on the second floor).

The building has four main stairwells to move between floors. Two of these stairwells are the only entry points to the fourth floor aside from the public/freight elevator. The third and fourth floors are blocked midway by art studios, with the fourth floor mid-building studio door locked at all times (unless access is needed by a person with a physical/mobile disability). The alternative routes around these restricted points are not practical or labeled and require a preexisting knowledge of the building.

Dysfunctional spaces such as the north entrance which is an art gallery with stairs going up or down, and the south entrance that combines a box office, performance hall foyer area, hidden access points to the stairwells, and a two-story art gallery only add to these issues.

According to the *2010 ADA Standards for Accessible Design*, the Fine Arts Center is certified as an accessible building. For example, there are ramps that lead to the south entrance of the building from accessible parking spots, providing an unobstructed path of travel into the building. The south entrance doors are equipped with automatic push button doors, and throughout the building, there are alternative paths to classrooms and spaces, accessible restrooms, telephones, and drinking fountains (2010 ADA).

However, these routes are not practical or obvious. These spaces lack consistent signage that takes into account visitors with or without a mobile/physical disability. These are the issues that have historically made this building difficult to navigate and have resulted in a confusing, disorienting, and frustrating experience of the space.

Students identified and worked through this problem in ART 155: Research and Application during the fall semester of 2016. ART 155 is a senior level design elective course taught in the fall that focuses on depth of research in relation to a design problem. This course is intentionally set at the senior level for students to demonstrate their design skills and to understand the role and value of research in relation to a design project. This course includes the identification of a problem, methods and triangulation of research, application of research findings to design problems, and refinement of student design skills — making this project a perfect fit for student learning.

All students in Art 155 were senior design students with double majors in advertising, journalism, computer science, and art history. It was a small class consisting of seven students — Bryan Nance, Paul Brenin, Justin Atterberg, Emily Walton, Michael Lopez, Bridget Fahey, and Madeline Wittenberg — which made for a tight knit collaborative group.

Using *IDEO's* Human Centered design philosophy and *A Designer's Research Manual* by Jenn and Ken Visocky O'Grady, students were engaged in the discussion of systems, human-centered design, mapping strategic research directions, identification and use of macro and micro design research methods, the analysis and triangulation of research findings, the application of research findings to design and material testing, iterative design, along with the production and installation of the Fine Arts Center wayfinding system.

Spanning ten weeks, the project was completed and installed on December 8, 2016.

PROCESS

Wayfinding is defined as information systems that guide people through a physical environment and enhance their understanding and experience of the space (Roux 2014). Such systems make a solid connection to IDEO's Human Centered Design philosophy, which is defined as a process that starts with the people you're designing for and ends with new solutions that are tailor-made to suit their needs (IDEO 2017).

Focusing on the person and their needs — especially physically/non-physically disabled needs — became central to this project by adding another layer of research and consideration. To help students navigate each part of this larger problem they used the Big6 model (Figure 2) of information literacy as they worked their way through each level of the during the 10-week timeline:

Week 1: Research and update architectural maps of the building complete with room numbers and icons for points of interest.

Week 2-3: Research, develop, and design take-away maps of the building.

Week 4: In pairs, research and design a preliminary wayfinding system that gets a user to and from one point in the building.

Week 5-8.5: Collectively build on prior research to design one cohesive system that addresses all of the touchpoints identified in prior research

Week 8.5-10: Production and installation.

(Figure 2. Big6 Information Literacy Model developed by Dr. Mike Eisenberg and Bob Berkowitz from A Designer's Research Manual.)

Week 1 : Architectural maps

In order to understand all of the spaces in the Fine Arts Center students needed to locate a layout of all five floors of the building (step 1). Immediately they went to the existing wayfinding maps (Figure 1) and found them outdated. The next step was locating the building manager for digital files (step 2), of which there were none. Only paper documents that have been copied over and over throughout the years existed.

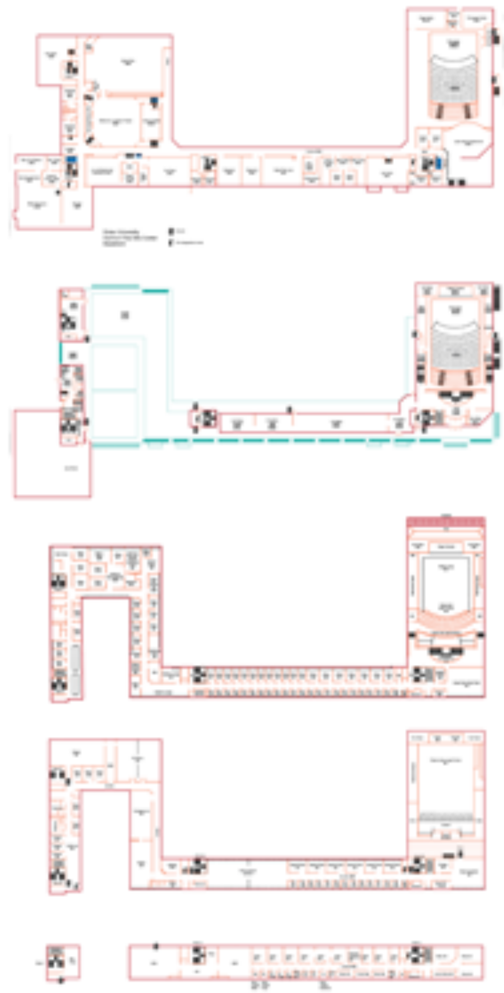
Moving through steps 3-5, students walked through the entire building documenting and correcting current rooms, hallways, stairwells, access points, elevators, locked areas, entrance ways, exit doors, blocked areas, and non-public areas on the current map.

Once completed, they conducted an interview with the Building Manager to identify mapping needs. This revealed the need for current room numbers, room names, restrooms, stairwells, elevators, fire extinguishers, phones, and exit/entrance points.

Students proceeded to create new digital maps in Adobe Illustrator for ease of accessibility and future revision (Figure 3).

Step 6 was conducted in close partnership with the Building Manager. Both parties determined that the font (Helvetica) was legible at this size (9pt) and all items were labeled and spelled correctly. The final printouts were in black and white on tabloid size paper (11”x17”).

(Figure 4. Student take-a-way maps)



(Figure 3. Redesigned Architectural Maps of the Harmon Fine Arts Center.)

Week 2-3 : Take-a-way map of the building

With the architectural maps completed students returned to the Big6 model to encounter a new challenge: creating take-away maps for visitors to use throughout the building.

Since they had just completed architectural maps of the building, the redefinition of the problem was how to design take-away maps of FAC that focused on the user in a building that has inconsistent signage?

Applying their previous knowledge of the building, the style of the architectural maps, and contemporary design in wayfinding, students set out to design take-away maps of the building. During this phase, questions surfaced such as:

Do I split the building between north and south? between majors?
What colors should I avoid/use for color-blindness?
How detailed should I get?
What size is the easiest to experience and use?
Where would a visitor pick this up?
Why would they be visiting FAC?

Students developed, and produced a variety of take-away maps (Figure 4) that included the necessary information to help a visitor identify paths around the building. The purple map (*top, second from left)* was chosen to accompany the final system.

Week 4 : Preliminary wayfinding systems

Students were paired and instructed to choose a room in the Fine Arts Center and create a preliminary wayfinding system to get a user with a physical disability to that room and back to the entrance. To help with this task ethnographic research was needed to find out how and why users move through the building in addition to visual research of the Drake Brand Standards for signage.

ETHNOGRAPHIC STUDIES - HUMAN CENTERED DESIGN

In an effort to understand the link between the interior space of the Harmon Fine Arts Center and its impact on wayfinding, students engaged in ethnographic research methods. Building on their own research experiences students identified a room in the building and documented their way to and from this point with photo ethnography. This served as formative research that helped them gain a better understanding of the intended audience's needs and behaviors (Visocky O'Grady 2009).

From this exercise, students began to understand and determine user touch points, decision-making areas, and where signage should be placed. For example (Figure 5) this student was navigating to the fourth floor painting studio and documented the frustration of locating stair 3, which is midway through the building and the only stairs to access the painting studio. Overall, students identified entering and exiting the stairwells and their access points as a major user touch point that was in need of wayfinding signage to orient the user in relation to the building and identify the major points of interest on the floor.

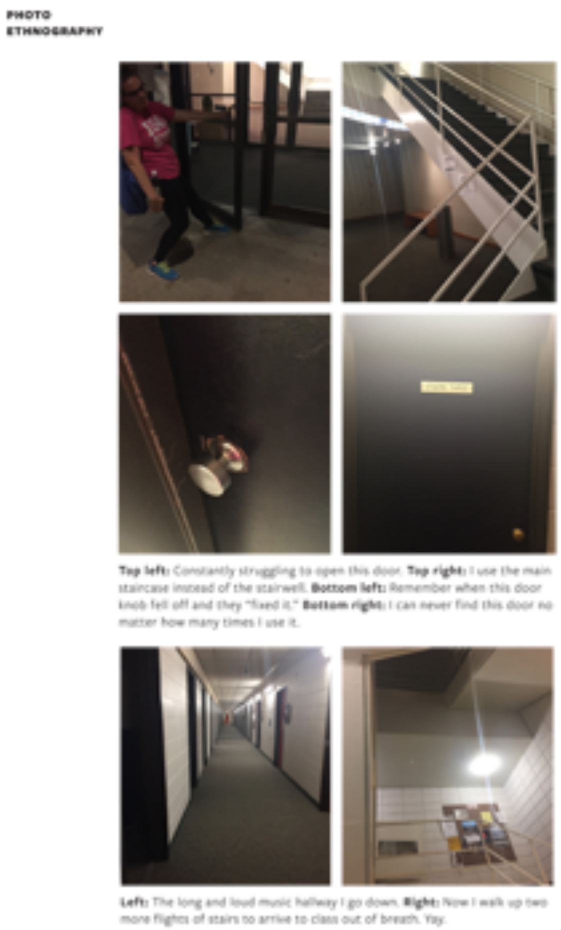


Figure 5. Emily Walton's photo ethnography research

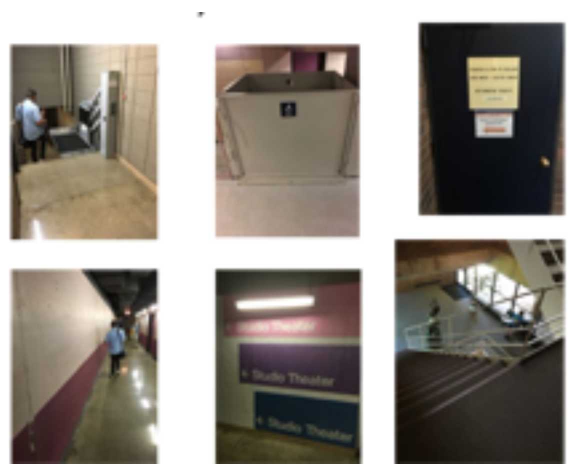


Figure 6. Paul Brenin's visual anthropology research

To better understand users and determine touch points, decision-making areas, and efficacy of current signage students also engaged in visual anthropology and observational research. Visual anthropology differs from photo ethnography by placing the camera in the hands of the researcher to document the perspective of the community under study (Visocky O'Grady 2009). Students assumed that most faculty, students, and administration would move through the space based on knowledge of prior visits to the building and that they would enter the building using the south entrance.

By documenting and analyzing visitor traffic through the building at various times during the day and week students confirmed these assumptions that a majority of students entered the building through the south entrance, which is the easiest entry point from other buildings on campus, vs. more faculty entering through the north entrance, which has the easiest entry to faculty and administrative offices. They found that the south entrance has multiple doors and access points, making it an overwhelming space for new visitors, but once in the space visitors had a preconceived notion of where to go based on previous visits. They also noted that there were no signs to indicate access to floors or specific points in the building if a user was physically/non-physically disabled (Figure 5 + 6).

Upon reflection, students identified entrances as spaces that need a comprehensive wayfinding system to help orient the user in relation to the building and help guide her/him to the nearest elevator (if physically disabled) or nearest stairwell (if non-disabled). In the stairwells, students noted that users would need signage to indicate what floor they were on along with what floors they could navigate to by going up or down. Once on the floor of their choosing, students noted that signage is needed to indicate what end of the building users were at, where important rooms were on that floor, and what direction users needed to travel in. When en route on the floor of their choosing, smaller signage would be needed to help users continue to their destination.

PRELIMINARY SIGNAGE SYSTEMS + EMPATHY

The Drake Brand Standards guide (Drake 2016) defined colors for the College of Arts & Sciences as blue, salmon, and orange and specified Whitney and Iowan Old Style for the official typefaces. This brand standard pdf specified photography, photography color treatment, and editorial guidelines but lacked a specific section on campus interior wayfinding and signage.

Throughout this project, interviews were conducted with students, faculty, and staff about their needs and potential opportunities to address. Talks with the building manager, department chairs, and students revealed the need to develop a friendly and digestible wayfinding system that included overall points of interest.

Two interviews, one with Professor Maura Lyons and the other with Associate Professor John Fender (*both of Drake University*), put forth key information about the building's architectural history and outdoor signage initiatives.

From recent research for an upcoming exhibition, Professor Lyons was able to provide the original architectural renderings and specifications for the interior of the Harmon Fine Arts center complete with paint colors, finishes, and typographic standards for signage (Figure 7, Associates 1971).

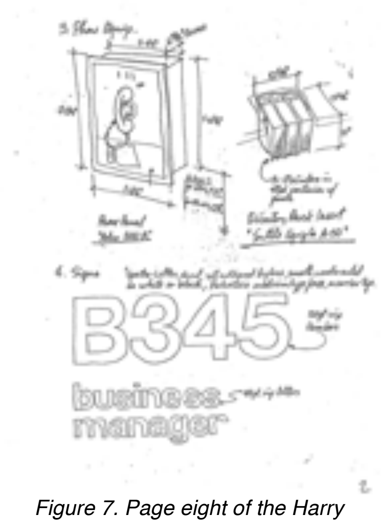


Figure 7. Page eight of the Harry Weese & Associates interior standard guide for the Harmon Fine Arts Center.

Through an interview with Professor Fender, the students discovered a Campus Signage Design Standard from a 2006 campus outdoor signage initiative by the Landscape Architecture + Visual Communications firm Mayer Reed. They stated that the design of the signage standard was developed by drawing upon the rich architectural heritage of mid-twentieth century buildings designed by Saarinen that shaped both academic buildings and student housing on campus (Mayer Reed 2006).

*8a. Group 1:
Emily Walton +
Maddi Wittenberg's preliminary wayfinding
system to office 281(second floor)*

*8b. Group 2:
Justin Atterberg,
Bridget Fahey, and
Michael Lopez's preliminary wayfinding
system to the third floor Drawing Studio*

*8c. Group 3:
Bryan Nance + Paul Brenin's preliminary
wayfinding system to the William S.E. Coleman
Studio Theatre (Basement Level)*

This built on the historical qualities of the Drake University Campus with a proposed and accepted typeface of Futura Medium, rather than the Drake identity standards of the time (Mayer Reed 2006).

With this knowledge, students were paired up and tasked with creating a preliminary wayfinding system to guide a physically disabled visitor from the entrance to a specific room in the building and back again. Decisions on the placement of wayfinding signage were drawn from their ethnographic research findings. Color, typography, and icons were pulled from interviews and current signage design trends.

As you can see (Figure 8a-c) certain groups worked with current typographic design trends, and the other groups worked from the architectural design standards. To gauge the efficacy and efficiency of their wayfinding systems Michelle Laughlin, Coordinator of Student Disability Services at Drake, volunteered to user test the systems.

USER TESTING + EMPATHY

Each group posted their system in the Fine Arts Center and tested it with Michelle, who happens to be a person with a physical disability who is unable to use the stairs. Throughout each test, a dialogue ensued between all parties, giving the students insight into what was successful and could be better executed within their systems (Figure 9).

Figure 9. Students user testing their wayfinding systems with Michelle Laughlin.

Group 1 (Figure 8a) discovered that the placement and location of their signage were well done but it lacked size and visual hierarchy, which made the signs blend into the wall. They also noted that a welcome directory at the entrance would have set the expectation of the signage throughout the building. Group 2 (Figure 8b) discovered that having a directory at the entrance and on the elevator helped Michelle orient herself in the building. Signage typography and color were easy to understand and coordinate with the existing floor colors of the building. However, when it came to the room signs, she indicated that they were not easily visible from a wheelchair and should include contact information for the Building Manager for access if the door is locked or closed. Group 3 (Figure 8c) discovered that the welcome directory at the entrance helped Michelle orient herself in the building and the typography and colors were easily understood. However she found that the elevator signage was missed due to the size and placement in the entrance. There was no indication on the directory what level the Theatre was on, and when she arrived, there was no signage to direct her to the lift access to the Theatre space.

Figure 10. Students experiencing the Harmon Fine Arts Center on knee scooters and in wheelchairs.

Upon debriefing, the students were inspired by the user's encouragement and the notion of how their wayfinding could continually and positively impact a large audience. They passionately discussed their systems and the building as a whole from the users' point of view.

To develop further empathy, I rented wheelchairs and knee scooters for the students to experience the building. As a class we navigated through each floor by using public and alternative routes. Students learned first-hand how a person with a mobile or physical disability would move through the building (Figure 10).

Using the public elevator to move between floors was expected, however, to get to locations on the third floor students needed to contact the building manager to provide a key to use the freight elevator from the second to third floor. Students rolled themselves onto the metal lined elevator next to a cleaning cart and waited as the metal cage doors were closed and they were lifted to the next floor. Once on the third floor, the elevator opened up to a computer lab that was previously a hallway. Depending on the time of day, a person with a physical or mobile disability might enter a class that is in session. Once off the elevator students rolled through the empty classroom and proceeded through a non-mechanical door into the hallway. The door to this lab is always locked due to liability issues and use of the freight elevator is possible only with the Building Manager present. For movement through that side of the building, students would have to rely on the building manager to let them in and out of the room and to use the freight elevator.

As we moved throughout the building students were instructed to observe their surroundings. From this perspective they needed to identify the height of their sightline, how others perceive and notice them, how they felt in the different spaces, and the difficulty of opening and entering non-mechanical doors. Students noted the difficulty in using the lift at the Studio Theatre, the de-humanizing effect of riding the freight elevator, no indications of which side the elevator will open causing students to exit backward, no indication of who to get in touch with to access the freight elevator and art studios, and an overall frustration with the lack of signage throughout the building.

This helped to understand movement through the building from a different perspective and assess any other human-centered needs for the final wayfinding system.

Week 5-8.5 : Condensing of signage style + type

Synthesizing all of the research and experience of the prior four weeks, students came together and were tasked with designing one cohesive wayfinding signage system.

Beginning with a signage standard, students reflected on their preliminary wayfinding system and incorporated the most successful parts of each one. Discussion ensued about whether to follow the institutions visual branding standards or stay true to the building's heritage and architectural standards. Citing the original architecture plans and the precedent of the outdoor signage initiative, students decided to stay true to the building's heritage. The fact that each floor of the building has its specified color palette that has been followed since its construction along with the architectural standards specifying Helvetica for the interior signage made a strong case to pursue this direction.

2ND ITERATION OF SIGNAGE - POST AND WALK THROUGH

Upon completion of the standards, students moved to the second iteration of the building's wayfinding system. Exploration of size, color, color combinations and line length were printed to size and viewed from a distance to test readability and legibility (Figure 11). At this point, the class needed to decide on a take-away map to include in the system. The proposals were evaluated and narrowed down to the one that best fit with the established standards and user needs.

Collectively the class decided on the size, weight, and color of wayfinding signage. Students paired up and created signage for each floor based on the standard. The first floor needed a welcome kiosk design — constructed for both north and south entrances — that included space for building hours, a pocket for takeaway maps, and a large area for "At-a-glance" wayfinding that included points of interest on each floor. Drawing from their experience in a wheelchair, students determined an appropriate height for the kiosk and orientation for the north and south entrances.

Figure 11. Size + color explorations

All floors needed large hall diagrams placed at the entrance to each floor, stairwell signs highlighting each floors main rooms, mid-floor diagrams to confirm directions, and accessibility information.

Signage was printed on bond paper, to size, and hung up around the Fine Arts Center and tested. This served as a proof to check and confirm directional arrows, spelling, room inclusion, color, and overall wayfinding. At this point we made corrections directly on the signage and later found that visitors of the building participated in making corrections.

Once this was completed, a third iteration was printed out to confirm all corrections.

Figure 12. Installation of wayfinding system

Week 8.5 - 10 : Production + Installation

Students were responsible for production and installation of the wayfinding system. This not only served to allow students ownership of the project but to teach them the value of file prep, professional practice, color comping, and troubleshooting. The final wayfinding signage was printed on PhotoTex fabric paper on a Epson InkJet large format printer. Students found that this material had the right amount of tack to be nondestructive to the Fine Arts Center and would hold up to the buildings fluctuating temperatures and humidity. The semi-permanent nature of this material makes it easy to revise/update over time if room numbers or offices change. The wayfinding system was installed on the last day of class, complete with take-away maps and building hours (Figure 12, 14). Digital/interactive maps were created for future app/touchscreen use (Figure 13).

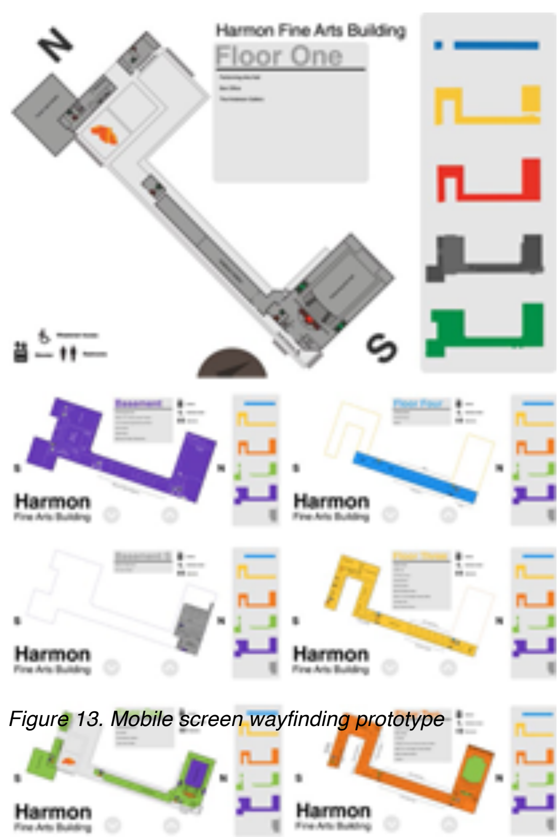


Figure 13. Mobile screen wayfinding prototype

FINAL TESTING + USER INPUT

The final testing occurred a week after the system was installed. Again, it was tested with Michelle Laughlin, Coordinator of Student Disability Services. She commented on how thoroughly thought out the system was, how the signage colors immediately resonated with the floor colors, and the consideration of informative signage aimed at people with mobile or physical disabilities.

Months after this system has been installed users of the building (Facilities Management, students, faculty, administration) have continued to thank and congratulate the class on their efforts and visitors have used over 100 take-away maps to navigate the building.

Furthermore the users of the building have become invested in the creation of this system and still feel the need to participate in critiquing and correcting signage as they see fit.

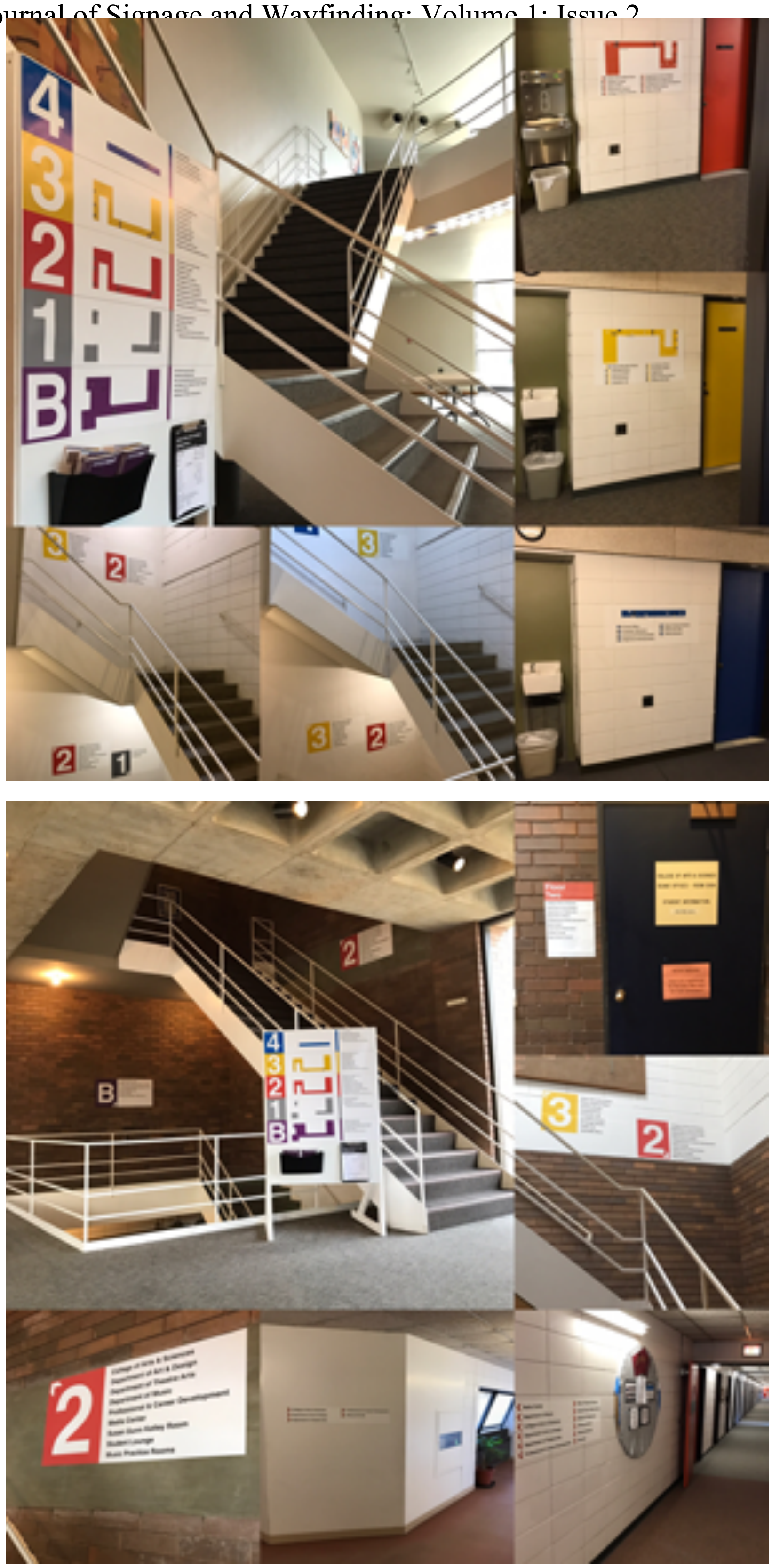


Figure 14. Fine Arts Center Wayfinding System

PEDAGOGY

From a teaching perspective there were many valuable pedagogical tools that were employed throughout this project. First and foremost was empathy. When the students piloted their first iteration and user tested it, they began to understand the users' needs and share their feelings from the users perspective, which helped them to look at the problem and understand the space from a different perspective. Seeing the importance and impact of their preliminary designs, students became self-motivated to engage and participate beyond earning a grade. However, it wasn't until they were in wheelchairs and on knee scooters — actually experiencing and interacting with the space and other visitors who were walking around them from the perspective of the user — did they truly understand the users' needs, feelings, and perspective of the space. This allowed students to compare and contrast mobility routes throughout each floor of the building as they began to realize how their identity, as a person with unimpaired mobility, was beginning to change. Emphasizing how identity is constructed, perceived, and portrayed would be a solid addition to understanding and expressing empathy.

Research and process were powerful tools as well. Knowing how to formulate a question and seeking out primary and secondary sources — library, online, observation — helped students identify paths of research and the value in seeking out information to answer the question even though it might not be used. For example: I am working on Accessibility because I want to find out what signage standards are available for physical impairments in order to understand how high signage should be placed in the Fine Arts Center. This question led students to an online search for accessibility standards where they found The Department of Justice's publication *2010 ADA Standards for accessible design*. Students vetted this lengthy document and found valuable information on how a building can be certified as accessible, but this document did not indicate height for signage placement. Even though this information wasn't directly applied to the project, students understood how their project fit within the larger context of architectural accessibility. As we had to work within time constraints, students missed out on developing quantitative and qualitative metrics to gauge the effectiveness of their system. Leaving two more weeks at the end of this project would have allowed for this final piece of research to be discussed and applied.

This brought up another pedagogical tool of vetting and analyzing information to understand what is reliable, relevant, and truthful (triangulating research). The more students researched the more they began to see overlapping themes and connections. For example, conducting ethnographic research and interviews allowed students to analyze and vet the relevant decision-making and pain points within the building, which determined the spaces for signage placement. They also drew upon their sightlines while in wheelchairs and knee scooters to determine the appropriate height of signage throughout the building.

Rapid prototyping was also a valuable tool throughout this project. Testing typography, point sizes, and colors of signage within the art building was crucial to identifying paths of travel and testing contrast within spaces. This pushed students to treat their ideas as non-precious and make decisions quickly based on space, research, and user needs. Scaffolding their skills from earlier courses where students are the users and decisions are impacted by peer and class critiques.

These pedagogical tools helped students to know and understand the larger context of their work, identify and construct a research path, analyze and apply a rich body of multi-disciplinary research to a design problem, and finally work through unforeseen issues quickly by rapid prototyping with a focus on user needs.

CONCLUSION

The goal of this project was for students to understand the value and application of a rich body of multidisciplinary research to a design problem. Building on this idea by focusing on visitors with a mobile/physical disability added depth and dimension to the research. Empathy played an important part to get student buy-in for the project and to motivate them to create work beyond rubric requirements and earning a grade. The students of ART 155 collaborated well together and successfully designed and installed the system on December 8, 2016.

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Do Motorists See Business Signs? Maybe. Maybe Not.

A Study of the Probability that Motorists View On-Premise Signs

Manuscript submitted for review to the
International Journal of Signage and Wayfinding

Christopher Auffrey[1]
Henry Hildebrandt[2]

[1]School of Planning, University of Cincinnati
[2]School of Architecture and Interior Design, University of Cincinnati

Abstract:

This study sought to answer questions about the extent to which on-premise signs (OPS) along US roadways attract the attention of passing motorists, based on a sample of OPS and roadway contexts captured in photo images from along the 3,073 mile length of highway US 50. 3M's Visual Analysis Software (VAS) was used to predict the probability that the selected OPS would be viewed by passing motorists. Results show that for all signs (n=467), the average probability of being viewed was about 57%, with that rising to about 66% for a "primary signs" group (n=100). These results are consistent with early research of motorist detection of on-premise signs in real-world contexts. 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, and both the businesses and their communities are foregoing the benefits that more effective signage would provide. This study also sought to determine whether the OPS of national and regional businesses are better able to attract the attention of passing motorists compared to the OPS of locally-based businesses. The results show the average probability of being viewed for the national and regional business OPS is significantly higher than for the local businesses, though both business types showed substantial variation in the probability of viewing. These results suggest an opportunity for the OPS of local businesses to be improved. Both findings here raise important implication for understanding how both local sign regulations and industry design and location standards factor into causing and resolving the problem. Finally, VAS was found to provide quick and inexpensive objective analysis of OPS in real-world contexts. Future research is needed to develop advanced protocols for the use of VAS in analyzing OPS in complex environmental contexts.

Key Words: On-premise signs; probability of viewing; Visual Attention Software

INTRODUCTION

On-premise signs (OPS)[1] provide a cost-effective and efficient mechanism for directing drivers to businesses (Kuhn et al., 1997; Ellis et al. 1997). OPS provide direction to current and new customers, build brand awareness and facilitate impulse sales (Conroy, 2004; Taylor and Sarkees, 2016; Taylor, Claus and Claus, 2005; Calori and Vanden-Eynden, 2015). They also contribute to an area's sense of place, whether it is the Las Vegas strip, New York's Times Square, a neighborhood business district, a historic downtown, or a suburban commercial corridor (Jakle, 2004; Baines & Dixon, 2008; Rickard & Stedman, 2015). The economic value of OPS for both businesses and communities makes them important tools for job creation and generators of the property, sales and income taxes that fund essential local services such as schools, police, fire, and roads (Auffrey, Hildebrandt & Rexhausen, 2011; Ellis, et al., 1997; Taylor & Sarkees, 2016).

The most effective OPS for both message communication and economic impact, are those that best capture the attention of their intended audience. There are a number of ways to increase the likelihood that a sign will be noticed. Size, illumination, contrast and location can all make a difference (Hawkins, 2011). Yet, the built and natural contexts in which a signs are located, and how the sign design and location respond to these, may be the most important factors for determining whether a sign captures viewers' attention, as evidence by different rates of detection of identical signs in different context (Auffrey & Hildebrandt, 2014; Garvey et al, 2002). A sign must be considered in the context of its environment, as it must draw attention away from the visual distractions that surround it. This is especially important for OPS along arterial highways where car and truck traffic, pedestrians, parked vehicles, trees and bushes, buildings, poles, wires and other signs, all compete for motorists' attention. Ultimately, to optimize the impact of any sign, there is a need to carefully consider the unique contextual elements of its use (Conroy, 2004).

How a sign attracts viewers' attention has important implications for interpreting studies of the return on investment (ROI) and the economic value of signage (EVOS). Studies that fail to carefully control for the contextual elements of OPS locations may falsely assume that all signs are equally effective in getting attention, and therefore understate the ROI and EVOS of those signs that have been carefully designed and located with respect to their unique contextual environments. Similarly, studies that only involve well designed and placed signs may overstate the ROI and EVOS for signs more generally.

Building on research demonstrating the importance of context, Kellaris and Machleit (2016) propose a conceptual model of signage as a marketing communication tool. Their model seeks to provide a framework for pulling together decades of signage research into a "big picture" so that "missing pieces of the puzzle" might be identified and pursued (10). As such, they identify five elements: 1) signage design; 2) viewer traits; 3) environmental context; 4) mediating processes; and 5) response variables. With respect to the environmental context, three issues are identified: 1) distance from viewers; 2) perspective or angle of view; and 3) relationship to

[1] On-premise signs are signs "erected, maintained or used in the outdoor environment for the purpose of the display of messages appurtenant to the use of, products sold on, or the sale or lease of, the property on which it is displayed" (Bertucci and Crawford, 2016, 21).

surrounding environment. This study focuses specifically on the relationship of OPS to their surrounding environment, and seeks to build a basis for measuring, assessing and understanding the relationship of a sign's environmental context to its effectiveness.

Signage design guidelines often assume that signs will be visible and commands sufficient attention so that issues related to distance and perspective are emphasized (Morris et al., 2001). Yet, research of signs in real-world contexts suggests that many OPS fail to capturing the attention of passing motorists (Auffrey and Hildebrandt, 2014; Hawkins, 2011; Garvey et al., 2002). This is consistent with the work of Chrysler et al. (2001), who demonstrated that street signage legibility distances on a test track were substantially longer that those measured in real-world driving. Similarly, Garvey et al. (2002) extended this research to OPS by demonstrating that up to 81% of their experimental OPS were not detected when placed in complex real-world contexts, and that legibility distances were substantially shorter for their real-world signs compared test track measurements. Yet, there is no published research of how actual commercial OPS perform in attracting motorists' attention in real-world roadway contexts. Clearly there is a need to better understand the extent to which OPS are effective in capturing viewer attention within the complex viewing environments in which they are used. That is what this study seeks to do. Toward this end, this study asks two fundamental but important research questions:

1) To what extent do the OPS along US roadways[2] capture the attention of passing motorists?
2) Are the OPS of major national and regional businesses, which are presumably better designed and located to accommodate their environmental context, better able to capture the attention of passing motorists than the OPS of locally-based businesses?

Answering these questions is important because if real-world OPS are failing to capture the attention of large numbers of motorists at appropriate distances because their design and placement inadequately responds to the competing visual stimuli within the environmental context of a motorist's viewshed, both traffic safety and customer access issues may result. Motorists require an adequate viewer reaction distance, based on vehicle speed and the complexity of the driving environment, in order to safely respond (slow, change lanes, turn toward business) to any OPS, once it is seen (Bertucci, 2006; Bertucci and Crawford, 2015). Motorists' whose attention is captured at less than the minimum reaction distance could brake excessively or make unsafe turns in order to respond to the OPS. Further, some of the opportunities afforded to business from effective OPS by communicating with customers, and to communities by a strong retail business base, may be missed. Differences in how the OPS of national/regional retailers capture the attention of motorists compared with local retailers may suggest the need for local economic development agencies to provide better OPS education and services to local businesses. Also, such findings could raise questions about OPS design and location practices, and the impact of local sign regulations on OPS effectiveness. It is in this sense that this research intends to identify one of the missing pieces of the signage research puzzle noted by Kellaris and Machleit (2016).

[2] For purposes of this study, the roadways of interest are those designated state and US highways, not part of the Interstate Highway System, intended to connect population centers and activities, and along which businesses are located because of the vehicle access afforded to existing and potential customers.

TOOLS FOR MEASURING MOTORISTS' ATTENTION TO ON-PREMISE SIGNS

The conventional research approach for measuring motorists' attention to signs real-world contexts (apart from test track studies) has involved researchers riding with drivers and recording their recall of signs, or the use of eye-tracking cameras. While methods these afford a scientific standard of measurement, they are relatively expensive and time consuming, and have the problem of limited generalization of results to other locations, as environmental contexts are described only in broad ways (e.g. high, medium or low complexity). This research sought to use an alternative tool that is scientifically valid and reliable, yet relatively quick and inexpensive. As such, it could be used to measure many motorists' attention to signs in multiple environmental contexts. 3M Corporation's Visual Analysis Software meets these requirements and was selected for this study (3M Visual Attention Software, 2017).

VAS was created to better understand what will be noticed from among the various visual elements that are part of signage, retail displays and advertising, by measuring visual attention based on how a typical human eye responds to a visual field. As such, it is intended to inform design decisions by adding objective information into what are often subjective design processes. VAS predicts visual attention based on the presence in an image of five elements: edges, intensity, red/green color contrast, blue/yellow color contrast, and faces. 3M's studies have concluded that these five elements are the primary drivers for attracting human visual attention (3M Visual Attention Software, 2017).

For signage researchers, VAS predicts the probability of whether a sign in its real-world context will be seen during the pre-attentive vision occurring during the first 3-5 seconds of viewing (3M Visual Attention Software, 2017). Pre-attention vision is innate to all humans, and is known not to be affected by gender, age or culture. Importantly, it is considered to be predictive of post-attentive vision as one consciously interprets what is being seen (3M Visual Attention Software, 2017). 3M's validation studies show VAS results to be 90-96% accurate when compared with eye-tracking studies, yet VAS offers tremendous efficiency compared to eye-tracking (3M Commercial Graphics Division, 2017; Zhang, et al., 2008; Tseng et al. 2009).

VAS provides five output products for assessing the probability that elements in a visual field will be seen in the first 3-5 seconds of viewing. Table 1 describes each of the output products and briefly describes their utility for signage research.

Table 1: Visual Attention Software Output Reports and Use in Signage Research

VAS Report	Description and Research Use
Areas of Interest	In each analyzed image, VAS allows "areas of interest" (AOIs) to be selected based on "visual priorities" of the researchers. The areas of interest report provides scores for each AOI indicating the percent likelihood of each selected area gaining attention in the first 3-5 seconds of being viewed. For signage research, this report can provide an estimate of the probability that a sign will gain a viewer's attention from the same visual perspective as represented in the photo.
Sequence	The sequence report provides an estimate of the order in which all the visual elements will gain attention in the first 3-5 seconds. For signage research, this report identifies in order those elements of the contextual environment that are estimated to have the highest percent likelihood of viewing, and thus potentially competing with signage for viewers' attention.
Regions	The regions report identifies those parts (regions) of the entire image with the highest percent likelihood for gaining attention in the first 3-5 seconds of being viewed. For signage research, like the sequence report, this report identifies elements in the contextual environment that have the highest percent likelihood of viewing, and thus potentially competing with signage for viewers' attention.
Visual Elements	The visual elements report gives you results for the five elements analyzed by VAS to estimate visual attention: edges, intensity, red/green contrast, blue/yellow contrast and faces. The report provides element scores for each AOI. For signage research, this report identifies from among the five elements the specific elements that are attracting attention.
Heatmap	The heatmap report uses color scales to display how viewers' attention is distributed across an entire image. Three color ranges are used to categorize the likelihood that a portion of the image will be viewed: red is for high likelihood of viewing; orange/yellow is used for medium likelihood; and blue is used for low likelihood. Areas with no color overlay have a very low probability of viewing. For signage research, this report contains information beyond what is provided in the regions report by providing color overlays for the entire image. This will assist efforts to understand where attention is most likely within the visual image.

Source: 3M VAS 2017 (http://solutions.3m.com/wps/portal/3M/en_US/VAS_NA/Home/How2/)

Consequently, for this research, VAS can be used to analyze photo images showing one or more OPS in their real-world environmental context, and predict the likelihood that each sign will be viewed, taking into account all the other the other contextual elements within the image that are competing for a viewer's attention (3M Visual Attention Software, 2017).

RESEARCH DESIGN

This study has used an exploratory research design to answer fundamental questions about the extent that OPS attract the attention of motorists. Such an approach is considered appropriate when the understanding of problems is in a preliminary stage, and when analytic methods are not well-developed. Further, an exploratory research design provides flexibility to address research questions to explore whether and to what extent do differences exist, and can be used to generate new research questions and hypotheses that explore the causes and solutions for those differences (Babbie, 2010).

Early studies established that OPS, when viewed in their real-world context, had wide variation in their likelihood of attracting motorist's attention, and could be altered to substantially increase motorist's attention though relatively minor design changes (Garvey et al., 2002; Auffrey & Hildebrandt, 2014). Yet, that work was based on a relatively small sample from limited contexts within two Midwestern cities. The purpose of the current research is to extend that earlier work to a larger, nationwide sample of OPS. In order to accomplish this, it was essential to have access to: 1) a nationwide database of OPS in a wide variety of environmental contexts; and 2) an analytic tool that can provide valid and reliable estimates of the probability motorists will view specific OPS within those environmental contexts. The design of this research has met both these conditions.

This research uses photo images of the OPS visible from the highway taken during the summer of 2013 as part of a cross-country research trip from Ocean City, MD to Sacramento, CA along highway US 50 (Fig. 1). US 50 was chosen because the OPS along US 50 vary dramatically, reflecting the route's wide range of natural, built and social contexts. US 50 allows observation of a historic and uniquely American road signage culture and its supportive environments, together with the evolving social / cultural conditions of small towns, and urban, suburban, exurban and rural communities. Further, it provides a visual laboratory of the full range of traditional and emerging signage designs and technologies.

Figure 1. Route traveled along highway US50

Earlier US 50 research documented the interplay of three critical factors for the communication effectiveness of on-premise signage: signage, buildings and context (Auffrey, Hildebrandt & Mehta, 2015). That research found that the important contextual elements were a result of the land use and land forms of the immediate and surrounding areas (including changes in elevation and sightlines), and the presence of potential visual obstructions from the presence of vegetation, poles, wires, vehicles, building and other signs. Other factors included the styles, heights, conditions and setbacks of buildings, and the width, alignment, profile and allowed speed of the road. The findings of the US 50 research project included:

- The environmental context of an on-premise sign has a major impact on whether a seemingly well-designed and located OPS can be seen by motorists;
- Many OPS use seemingly standard designs and placements, often based on national franchise requirements, are difficult to see because they fail to account for environmental context;
- Many of the OPS that are difficult to see could be redesigned and/or moved, seemingly within the scope of commonly accepted sign regulations, to better account for their environmental context and thereby improve their communication effectiveness.

(Auffrey & Hildebrandt, 2014)

DATA

One hundred photo images were selected from among a collection of 4,122 digital photo images of OPS visible from the highway taken during the trip along highway US 50. Each photo image contains from two to eight clearly visible OPS, with an average 4.67 OPS per photo and a total of 467 OPS that were part of this analysis. All the selected photos images were taken in full-daylight through the passenger side of the front windshield of a car while driving at near-posted speeds, or at the speed at which traffic conditions safely allowed, along small town, urban, suburban, exurban and rural sections of US 50. Photo were intentional taken in such a way to capture the visual images from the perspective of the motorists at which the OPS were directed. While the photos were taken from the passenger side of the vehicle, given that small sedans were used for the trip (2013 Hyundai Elantra, 2012 Fiat 500, and 2013 Chevrolet Cruze) it is assumed that the perspective of the photos is reasonably representative of what would be seen by both the driver and front seat passenger. The researchers sought to record images of OPS that included the natural and built environmental contexts in which the OPS were placed. Images were collected for both older and newer sign designs and styles. All photos were taken using a Nikon D50 with autofocus, 1/500 second exposure, no flash, using a 180mm telephoto lens and varying levels of magnification.

The intent of the field research was to collect representative photo images to build a comprehensive and representative digital database to document and analyze the multiple and varied types of OPS generally found in the US, and the full range of visual contexts in which those OPS compete for motorists' attention. US 50 was selected for collecting the photo images of OPS because it is a major coast-to-coast highway that is not part of the Interstate highway system. For most of its 3,073 mile length, US 50 provides direct access to roadside businesses and travels through a mix of development conditions (rural, small town, exurban, suburban and urban), landforms (plains, rolling hills, mountains and deserts), and OPS types (pylon, pole, monument, wall/roof/parapet, projecting, awning, sidewalk, window, buildings as signs) with a variety of types of illumination (unlit, internally illuminated and externally illuminated). As such, US 50 was considered to serve as a comprehensive visual laboratory of OPS types and the multiple contexts in which OPS are displayed.

All of the 100 selected photo images for the current research are forward-facing as would be viewed by a front-seated passenger or the driver, approximately centered horizontally on a “primary sign” within a 60 to 120 degree horizontal and 60 to 80 degree vertical visual field. Each image’s primary sign was so designated because it was positioned to be clearly visible, and given road conditions and posted speeds, there would be adequate viewer reaction time (4-6 seconds, depending on driving environment, according to the US Sign Council) for a driver to safely respond to the sign by turning off the road toward the associated business (Bertucci and Crawford, 2015). Consideration of likely vehicle speeds is essential because it is the combination of viewer reaction time and speed that determine the viewer reaction distance. At 35 MPH, a distance of about 200-300 feet (depending on the complexity of traffic environments) is need for motorists to react to seeing an OPS. At 55 MPH, the necessary viewer reaction distance of about 325 to 485 feet. As such, the images selected for this analysis were chosen because they were considered to approximate these distances and as such, reflect the range of real-world conditions under which business owners expect motorists to view their signs.

3M’s VAS software was used to analyze each of the 100 photos images. In each of the images, up to eight OPS were selected to be analyzed using VAS’s Area of Interest (AOI) tool, with a total of 467 OPS selected for AOI analysis, or an average of 4.67 OPS per photo image. Use of the AOL tool was especially useful for this research because it allows separate estimates of the probability of viewing for each sign in a photo image.

The number of OPS selected in each image varied depending on the number of “prominently visible” OPS in each image. In each image, the OPS were selected in order, from the most prominent (primary sign) to the least prominent OPS, based on the researcher’s judgement of each sign’s relative proximity to the center of the visual field, and the degree to which it commanded a viewer’s attention. This selection was based on the researcher’s judgment of the probability that a sign would be seen by a passing motorist, based on what can be seen in the image. The researchers consider that under these conditions, our analysis can provide valid and reliable estimates of the likelihood that the signs would capture a driver’s attention, based on the perspective afforded by the image.

Also, as indicated earlier, the selection of the primary sign in each image required that the point at which the sign is viewed (from where the photo image was taken) must allow adequate time for a motorist to safely respond to the sign, should they choose to do so. While this last condition is not required for the branding functions of OPS, it is critical for wayfinding and generating impulse sales. As such, this research differentiated the “primary OPS” from the other “non-primary OPS” in each image.

Further, it was considered that primary signs, being so designated because they are more centered and prominently visible in the images, may better conform to the VAS algorithm for the probability of viewing, and as such, any difference in their probability of viewing compared to the non-primary signs may reflect camera angle (or viewing angle), as opposed to differences in sign design or environmental context issues. To this end, all signs were assigned to one of three probability categories, based on the VAS estimate of their probability of being viewed. Similar to the categories used in the VAS Heatmap output, signs with probabilities of 0% to less than 40% were assigned to the low probability of viewing category, 40% to less than 70% were assigned to the medium probability of viewing category, and signs with probabilities of 70% or more were assigned to the high probability of viewing category.

Finally, it was considered that the signs of national and regional businesses may have better access to sign design and placement services, and therefore have a higher probability of being viewed, compared to the signs of local businesses. Consequently, each of the 100 primary signs was reviewed and as designated representing either a national/regional business or a local business.

Data was collected and entered into an SPSS database for each sign's attributes: 1) designation as a primary or non-primary sign, 2) probability of viewing, 3) low, medium or high probability of viewing category, and 4) whether it represented a national/regional business of a local business. SPSS then was used to perform the following three analyses:

1. For the probability of viewing a sign among the three sign groups (primary, non-primary, or all signs), descriptive statistics were calculated and a difference of means analysis used for to test for significant differences in the mean probability of viewing between the primary and non-primary groups;
2. For the proportion of signs in either the low, medium of high probability of viewing categories, descriptive statistics were calculated and a difference of proportions analysis used to test for significant differences in the proportion of primary signs in each category compared with the non-primary signs;
3. For the probability of viewing the signs of national and regional businesses compared with the signs of local businesses, descriptive statistics were calculated and a difference of means analysis used to test for significant differences in the probabilities of viewing the signs of national and regional businesses compared to the signs of local businesses.

FINDINGS

The results of the VAS analysis were tabulated using SPSS software. As show in Table 2, for all 467 signs, the average (mean) probability that a motorist would view one of the signs was 56.6%, indicating there was a 43.4% chance, on average, that motorists would not have viewed one of the signs. The average probability of viewing was 65.9% for the primary signs (n=100) and 54.0% for the non-primary signs (n=367).

In addition, the average probability of viewing for the primary signs was found to be significantly higher than the average probability for the non-primary signs. This suggests that the primary OPS may be better designed and/or located within their environmental context, at least from the visual perspective provided by the photo image, compared with the non-primary signs in the same photo image.

Also, the variability of the probability of viewing, as shown by the range of probabilities, was substantial for both primary signs (range: 17% to 98%) and non-primary signs (range: 5% to 98%).

Table 2: Probability Motorists Will See Sign, by Sign Group

Sign Group	Percent Probability of Viewing					
	Average (Mean)	95% CI	50^{th} Percentile (Median)	Minimum	Maximum	Range
All Signs (n=467)	56.6	[55.0, 58.2]	56.0	5	98	93
Primary Signs (n=100)	65.9*	[62.3, 69.5]	66.5	17	98	81
Non-Primary Signs (n=367)	54.0	[52.2, 55.8]	54.0	5	98	93

*Significantly higher mean probability at the p.=.000 level

Apart from the probabilities that a motorist would view a selected sign, it was of interest to determine to what extent the proportion of signs in each probability category might differ by sign group. As shown in Table 3, the primary signs group had a significantly higher proportion of signs in the high probability of viewing category, compared with the non-primary sign group, again suggesting that the primary OPS are representative of OPS that are, on average, better designed and located for their environmental context. As shown, the non-primary group had significantly higher proportions in both the low and medium probability of viewing categories.

Table 3: Proportion of Signs in Probability of Viewing Categories by Sign Group

Sign Group	Proportion[1] of Signs by Probability of Viewing Category		
	Low	Medium	High
All Signs	0.156	0.627	0.216

(n=467)			
Primary Signs (n=100)	0.080	0.510	0.410*
Non-Primary Signs (n=367)	0.177*	0.659*	0.163

*Significantly higher proportion in category between groups at the p.=.000 level
[1]Proportions may not total to one due to rounding

In addition to the differences between the primary and non-primary signs, it was of research interest to assess how the probability of a motorist viewing a sign for a national or regional business compares with the probability of viewing a sign for a local business. Because the probability of a motorist viewing the primary signs had been found to be significantly higher, the comparison of the national/regional and local signs was limited to only the primary signs group. As shown in Table 4, the signs for national and regional businesses have a significantly higher probability of being viewed by a motorist than do the sign for local businesses.

Table 4: Probability Motorist Will See Sign by Businesses Type (National/Regional vs. Local)

Business Type	Percent Probability of Viewing					
	Average (Mean)	95% CI	50th Percentile (Median)	Minimum	Maximum	Range
Primary Signs (n=100)	65.9	[62.3, 69.5]	66.5	17	98	81
National/Regional (n=49)	70.4*	[65.5, 75.3]	71.0	25	98	73
Local (n=51)	61.6	[56.7, 66.5]	61.5	17	98	81

*Significantly higher mean at the p.=.016 level

DISCUSSION AND IMPLICATIONS

As exploratory research, this study has been concerned with both responding to research questions and broader methodological issues. The first research question asked to what extent the OPS along US roadways are attracting the attention of passing motorists. The results of this research found that for the all signs group, the average probability of being viewed was about 57%, with that rising to about 66% for the primary signs group. These numbers are consistent with the work of Garvey et al. (2002), who found in a small study that in two separate location, only 60% and 53% of their experimental on-premise signs were detected during daylight testing in real-world contexts. While the methodologies in this study and the Garvey et al. study were largely different, the similar findings suggest that a substantial proportion of the on-premise signs along roadways in the US are indeed not being viewed by motorists to the extent that businesses and communities would hope.

The first research question is further answered, in part, by the large variation in the probability of an OPS being viewed (Table 2). For both the all signs group and the non-primary group of OPS, the range of the probability of being viewed was from 5% to 98%, and for primary signs the range of probabilities was from 17% to 98%. This variation also is displayed in the distribution of the signs across the probability categories (Table 3). Overall (all signs group), about 16% of the OPS (nearly one in six) had less than a 40% probability of being viewed while only about 22% (one in five) had a 70% or greater probability. Here, the differences between the primary and non-primary signs are substantial as well as statistically significant. Only 8% of the primary signs fell into the low probability category compared to nearly 18% of the non-primary signs. This was reversed for the high probability category, where 41% of the primary signs and only 16% of the non-primary signs were classified as such. These results suggest that while some OPS perform quite well, there is a substantial inconsistency in the performance of OPS generally, with more than three-quarters (78.3%) having less than a 70% probability of being viewed. Consequently, with respect to the first research question, while 57% to 66% of the OPS have a high probability of being viewed, a third or more do not.

This large variation in OPS performance is indicative of both a problem and an opportunity. The problem is that businesses and communities are losing out on the potential social (including traffic safety) and economic benefits of OPS that are better designed and located for their unique environmental context. The opportunity is that the problem can be improved upon, and there good reason to think that the benefits of doing so may very well exceed the costs. This raises important implication for understanding how local sign regulations and industry design and location standards factor into causing and potentially resolving the problem.

The second research question asked whether the OPS of major national and regional businesses are better able to attract the attention of passing motorists compared to the OPS of locally-based businesses. The results (Table 4) show that when using data for just the primary signs group, the average probability of being viewed for the national and regional business OPS (70.4%) is significantly higher than for the local businesses (61.6%). Both business types showed substantial range in the probability of viewing, from 25% to 98% for the national and regional businesses compared to 17% to 98% for the local businesses. Consequently, the results suggest that the national and regional OPS are indeed better able to attract the attention of passing motorists than the OPS of local businesses, though both exhibited substantial variation in doing so. Given that the OPS for national and regional businesses perform better, there is clearly an opportunity for the OPS of local businesses to be improved.

Methodologically, the challenge in this study has been to test an alternative means for evaluating signage effectiveness in real-world contexts, given the limitations of traditional road sign recall and eye-tracking approaches. It is well established that responding to environmental contexts is an essential considerations for ensuring that sign are viewed, and earlier work has documented the substantial variety of OPS types and their varied environmental contexts. A tool was needed that could more efficiently provide valid and reliable measures for assessing the attention-capturing performance of similar signs in dissimilar real-world contexts. The use of VAS has allowed this assessment through objective analyses that would not have been possible otherwise.

Yet, despite the advantages of VAS, significant challenges remain for its use in fully understanding how OPS capture the attention of passing motorists. In the current research, VAS was used to analyze images reflecting a single moment in time in what is an inherently dynamic process of viewing signage (and other things) while driving. In a real-world context, as a motorist proceeds on the roadway, the views of OPS and their environmental context are continually changing. As such, the extent to which a particular OPS is capturing the attention of a motorist is continually changing, as well. The VAS estimate of the likelihood that an OPS will capture the motorist's attention will change as the vehicles moves and the sign's visual context changes. As such, the VAS results must be interpreted with these limitations in mind.

This research used VAS to analyze photo images of OPS taken at approximately the minimum viewing distance (based on vehicle speed and traffic conditions) that would allow the motorist to safely respond to the OPS by getting off the highway and going to the business. It is assumed that at shorter distances to the OPS, many motorists could not safely respond, and the OPS is less useful for wayfinding or attracting impulse customers. At longer distances, while motorists would be better able to respond to the OPS if it were to capture their attention, the added distance may increase the potential for visual complexity with competing elements that direct attention away from the OPS.

Future signage research using VAS would benefit from the development of advanced protocols for its use in the dynamic visual environments found along roadways. For example, a more valid and reliable measure of a sign's ability to capture motorists' attention might be reflected in an average (mean) likelihood of viewing calculated over the distance from when the sign is first visible until the minimum viewing distance is reached. Automated versions of such a tool could be extremely useful for sign companies in the design and placement of OPS in real-world contexts. Also, such a tool may be helpful for local and state transportation departments in the placement of traffic safety and directional signage. In addition, planning agencies could use such a tool to model the impact of sign codes on OPS effectiveness.

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