PSYCHOLOGICAL ANALYSIS OF DEGREE OF SAFETY IN TRAFFIC ENVIRONMENT DESIGN

CHARLES J. HOLAHAN

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PSYCHOLOGICAL ANALYSIS OF DEGREE OF SAFETY IN TRAFFIC ENVIRONMENT DESIGN

Charles J. Holahan

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For

Texas Office of Traffic Safety
State Department of Highways and Public Transportation
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16. Abstract

Recent on-site accident investigation studies have estimated that between 10 and 25 percent of automobile accidents involve distraction as a principal causative factor. This report presents the findings of a research project designed to study the relationship between visual distractors in the roadside environment, such as advertising signs, neon lights, and gaudy billboards, and traffic safety. This project has involved the definition, operationalization, and measurement of visual distractibility in the traffic environment, including an analysis of distractions attributable to private signs and lights in the vicinity of public signs and signals and of distractions caused by an overload or improper placement of public signs.

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*Traffic Signals, Proximate Distractors, Color Distractors, Number of Distractors.

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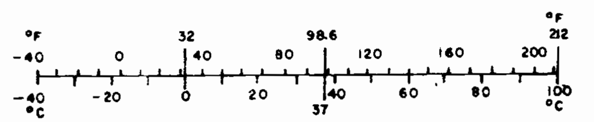
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

The contemporary roadside environment in many urban and suburban areas is typified by a burgeoning visual complexity, with advertising signs, neon lights, and gaudy billboards dominating the visual landscape. Surprisingly, little research has examined the relationship between this array of potential visual distractors in the roadside environment and traffic safety. The need for such research is underscored by recent on-site accident investigation studies which have estimated that between 10 and 25 percent of automobile accidents involve distraction as a principal causative factor.

This project's ultimate goal has been to facilitate and support implementation at the state level of traffic safety standards involving type and placement of both public road signs and private signs and lights located proximately to the traffic environment. This effort has included two principal objectives: (1) collecting and synthesizing available information dealing with traffic safety and the legibility of the visual traffic environment; and (2) identifying and measuring those variables and dimensions in the visual environment associated with a reduction in legibility. While considerable past inquiry has examined perception of the target traffic signal, few research efforts have systematically investigated perception of the target as a function of distractions in its environmentalbackground. This project has involved the definition, operationalization, and measurement of visual distractibility in the traffic environment, including an analysis of distractions due to private signs and lights in the vicinity of public signs and signals, in addition to distractions caused by an overload or improper placement of public signs. This effort was divided into: (1) a laboratory-based feasibility study employing a simulation technique involving a measure of reaction time to a target traffic signal embedded in a background of contrasting types and numbers of distractors and (2) a field-based feasibility study in which specific characteristics of traffic accidents were related to the type and number of distractions at a range of intersections in Austin.

The laboratory-based study investigated the effect of: (1) the number of distractors (2, 4, 6, or 10), (2) the color of distractors (six combinations of red, orange, and the cool colors -- blue, green, and black),

and (3) the location of distractors (proximate or distant) on the perception of a target stimulus (stop sign). Reaction time in responding to the target stimulus was the response measure.

A 4 by 6 by 2 analysis of variance with reaction time as the dependent variable showed statistically significant main effects and both two-way and three-way interaction effects. Of the three dimensions under study, proximity was found to have the greatest effect on reaction times. This suggests that the dominant process was the subject's inability to discriminate figure from ground.

In general, the results of the laboratory-based study suggest that: (1) appropriate ordinances be established to legislatively limit the effect of distractors and (2) engineering decisions involving design changes in the target signal be oriented toward counteracting the potential negative effects of the background distractors.

The field-based study systematically investigated the relationship between signs located proximally to urban traffic intersections and the number of traffic accidents at those intersections. Sixty intersections were randomly selected from a list of intersections within the city of Austin having at least one accident during the 1975 calendar year. The number of at-fault accidents attributed to drivers approaching from each direction was computed for each intersection for the 1975 calendar year.

Every sign observable at an intersection was classified along three dimensions -- type of sign, size, and dominant color. Examination of the correlation between distractor dimensions and at-fault accidents for both traffic signal controlled and stop sign controlled intersection approaches indicates: (1) no distractor dimensions demonstrated a significant relationship with at-fault accidents for traffic signal approaches and (2) three distractor dimensions (total signs, large signs, and non-red signs) demonstrated a significant positive relationship with at-fault accidents for stop sign intersections. A particularly strong picture of the relationship between signs and traffic accidents emerged when data were examined separately for stop sign approaches showing two or more annual accidents, controlling for the effect of traffic flow. Under these conditions, four distractor dimensions (total signs, private signs, large signs, and non-red signs) demonstrated a strongly significant positive relationship with at-fault accidents.

Based on these findings, a summary picture of the relationship between distracting signs in the roadside environment and traffic accidents can be presented. First, there is no evidence that signs present a traffic safety problem at intersections controlled by traffic signals. There is, however, evidence that signs are related to accidents at stop sign controlled intersections. The differential effects of signs on traffic signals and stop signs are probably due to a number of factors. Most important is probably the fact that, in the case of stop signs, distractors and targets are the same medium, while with traffic signals, the mediums differ.

The results of the field-based study support a number of practical suggestions that may be offered to traffic engineers concerned with reducing the effects of distracting stimuli in the roadside environment. First, there is a need for appropriately restrictive legislation concerning the number and size of commercial signs located proximally to stop signs. Where proximate distractors cannot be legislatively restricted, a wider range of engineering alternatives may be needed to counteract their effects, such as designing a larger or brighter target traffic device or employing a neutral background shield to more effectively contrast the target with its surrounding context. Alternatively, when legislative or design alternatives are not feasible, traffic signals should be employed rather than stop signs at sites where a significant number of commercial distractors are present.

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I. FACTORS CONTRIBUTING TO DISTRACTION IN THE TRAFFIC ENVIRONMENT

As automobile drivers have a limited amount of attention available for performing the driving task, any environmental elements which divert attention from that task may potentially relate to traffic accidents. In fact, three on-site accident investigation studies have estimated that distraction may be a contributing factor in from between 10 to 25 percent of automobile accidents.[1] The true impact of this factor is difficult to verify because this type of information is often withheld by motorists involved in accidents since to admit being distracted is tantamount to admitting liability. Advertising, which is designed to draw the motorist's attention (often, at highly traveled intersections and roadways, where demands on the driver's attention are greatly increased), seems to be a potent example of distraction in the traffic environment.

Two studies have indicated a strong correlation between the number of elements in the roadside environment and the number of accidents -- that is, the greater the complexity of the environment (the more intersections, commercial buildings, driveways, traffic signals, etc.), the greater the accident frequency.[2] In fact, both studies have arrived at regression formulae for predicting the frequency of accident occurrence that are fairly reliable. While these studies note the relationship between a complex traffic environment and accidents, they do not speculate on why the relationship exists. One possible explanation is that in the more complex situations there are more elements competing for the driver's attention than he or she can handle while still driving in a safe manner.

---

[1] C.R. Ruch, D.F. Stackhouse, and D.J. Albright, Jr., "Automobile Accidents Occurring in a Male College Population," American College Health Association Journal 18 (April 1970), pp. 308-312; A.B. Clayton, "Road-User Errors and Accident Causation," paper presented at the 17th International Congress of Applied Psychology, Liege, Belgium, 25-30 July 1971; and U.N. Wanderer and H.M. Weber, "First Results of Exact Accident Data Acquisition on Scene," Proceedings, 3rd International Conference on Occupant Protection, New York, 1974, pp. 80-94.

[2] J.A. Head, "Predicting Traffic Accidents from Elements on Urban Extensions of State Highways," Highway Research Board Bulletin 208 (1959), pp. 45-63; and J. Versace, "Factor Analysis of Roadway and Accident Data," Highway Research Board Bulletin 246 (1960), pp. 24-32.

Connolly, an optometrist and consultant on road user characteristics to the U.S. Highway Research Board, has noted:

> We all know it takes time to see. Estimates and measurements have shown that man can fixate an event every half of a second, which means that for every 88 feet he travels at 60 miles per hour, he can handle and assimilate two events. . . . Studies have shown that when a[n airplane] pilot is overloaded with perceptual stimuli (instruments and audio communication), he often exceeds his sensory capacities and may miss both visual and auditory messages that may subsequently lead to accidents. Likewise, too many signs, traffic control lights and flashing signals, and brake lights, plus vehicular and pedestrian traffic, overload a driver's psycho-physiological abilities.[3]

Several elements in the roadside environment have been considered as common distractors -- billboards, private signs and lights, public signs, and buildings and objects close to the roadway. In fact, there are ordinances and restrictions in nearly all cities which regulate the number and size of signs and their placement, color, and light intensity; building setbacks; and parking restrictions. Quite often these restrictions and their variances are made by policy makers who base their decisions not on actual traffic safety evidence but on their own hunches or observations. For example, Shoaf describes how San Francisco supervisors developed a well-defined, restrictive policy for the placement of advertising signs near freeways, even though they acknowledged that the evidence relating the signs to accidents was inconclusive.[4]

In this section we will discuss the state-of-the-art of field research on distractors such as those mentioned above. For each element we will first note popular conceptions about its distracting quality, then examine the evidence from actual field studies. Very few studies have dealt with the issue of distraction in the laboratory. Forbes _et al_. did describe a crude "distraction" substudy in one article,[5] but the findings were disappointingly vague.

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[3] P.L. Connolly, "Visual Considerations: Man, the Vehicle and the Highway," _Highway Research News_ (Winter 1968), pp. 71-74.

[4] R.T. Shoaf, "Are Advertising Signs Near Freeways Traffic Hazards?" _Traffic Engineer_ (1955), pp. 71-76.

[5] Forbes _et al_., "Color Brightness in Simulated and Full Scale Traffic Sign Visibility," _Highway Research Record_ 216 (1968), pp. 53-65.

A. Billboards

Outdoor advertising which undermines the traffic informational system of signs and lights and detracts from the natural landscape is not in the public interest. An opinion survey conducted by the Boston Redevelopment Authority found negative public attitudes toward large advertising signs. A majority of the respondents agreed that billboards were distracting and pointed out that they were inappropriate at such locations as major road intersections, along major roads, and on highways approaching the city.[6]

Two studies have provided correlational evidence that billboards are a traffic safety hazard. The Highway Planning Survey of the Minnesota Department of Highways conducted a two-year study on 420 miles of two-lane and 90 miles of three- and four-lane roadways and found a .97 correlation coefficient between the presence of advertising signs and accident rates.[7] Madigan-Hyland, Inc., found that even though advertising devices were visible to drivers on only one-eighth of the New York State Thruway's 1100 miles of roadway, almost one third of the accidents "attributed to driver-inattention" occurred on these stretches of roadway. The engineers found that "there was an annual average of 1.7 accidents/mile due to driver-inattention on the portions where advertising devices were visible; and only 0.5 of an accident/mile for this cause when the devices were not visible".[8] In contrast, the Boston group cites a study which claims statistical evidence showing that billboards are not a safety hazard.[9] Therefore, the argument that billboards are directly related to traffic accidents is not as yet conclusive.

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[6]Boston Redevelopment Authority, City Signs and Lights (Boston, 1971).

[7]Minnesota Department of Highways, Minnesota Rural Trunk Highway Accident, Access Point and Advertising Sign Study (1952).

[8]Madigan-Hyland, Inc., Signs and Accidents on New York State Thruway, report prepared for the New York State Thruway Authority (February 1963).

[9]A.R. Lauer and J. McMonagle, "Do Road Signs Affect Accidents?" Traffic Quarterly, (1955), pp. 322-329.

B. Private Signs and Lights

Many of the arguments leveled against billboards have also been directed toward private signs (usually those signs which identify a commercial establishment). Whereas billboards are of standard size, these signs vary greatly in size and are often illuminated. Many cities have strict ordinances proscribing the extent to which such signs can reasonably attract a driver. Often they are based on vague ordinances which prohibit "any change in light intensity, motion, or color which subconsciously fixates or attracts the eyes of the motorist when they should be concentrating on driving." Thus they set limits on changes in light intensity and motion, but frequently these limits are established from intuition.

In this case, policy makers have no field research on which to base their decisions. Thomas indicates that one of the strongest visual stimuli is a flashing light.[10] When seen out of the corner of the eye, the flashing light will cause the eyes to swing involuntarily to focus on it. Similarly, when an object is difficult to identify (as when a sign is in motion) the eye fixates on it longer and jumps back to view it repeatedly.[11] However, these findings do not come from the field but from laboratory studies.

Forbes' study notes that other lights and signs surrounding a traffic marker can create visual clutter and interfere with the driver's perception, causing errors.[12] A similar study by Brown and Monk looked at an individual's ability to pick out a target from a complex assortment of non-targets and found surprisingly similar results.[13] Search performance for a target was impaired by the complexity of the area surrounding the target. Isolated targets were more easily

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[10] E. Llewallyn Thomas, "Movements of the Eye," Scientific American (August 1968), pp. 88-95.

[11] W. Ewald and D. Mandekker, Street Graphics: A Concept and a System (Washington, D.C.: The American Society of Landscape Architecture Foundation, 1971).

[12] T.W. Forbes, "Review of Visibility Factors in Roadway Signing," Highway Research Board Special Report 134 (1972), pp. 37-38.

[13] B. Brown and T.H. Monk, "The Effect of Local Target Surround and Whole Background Constraint on Visual Search Times," Human Factors 17, No. 1 (February 1975), pp. 81-88.

detected than those surrounded by non-targets. To make target signs and signals stand out, Olsen suggested the use of an artificial surrounding such as a flat black metal screening to provide a break in the cluttered environment.[14] This would increase the target value of a sign. Unfortunately, such a move would constitute a costly change in the existing traffic information system and would be difficult to implement.

C. Roadside Objects

Another area of potential distractors is composed of roadside objects. These would include buildings, parked cars, barriers, hydrants, and "street furniture" that appear to impinge upon the driver's right-of-way. Although the distracting value of these objects relevant to the other distractors in the travel environment has not been investigated, they are considered frequently as traffic hazards.[15]

The field research on roadside objects is unique in that this is one of the few areas where actual controlled research -- as opposed to correlational studies -- has been conducted. Case *et al*. looked at the effect of roadside barriers on lateral displacement of passing vehicles, which were photographed as they passed. By presenting combinations of three different-sized barriers at three different distances from the roadway, they found that the reaction to distance was of a higher order than reaction to size and that there was significant interaction.[16] A similiar study replicated the results for distance and also found that the speed of the vehicle affects the displacement, which occurs sooner at higher speeds. They speculate that relative to the driver, the displacing object moves laterally across the retina with angular velocity relative to the speed.[17] Both studies were conducted in fields with very low complexity (airport runways) and

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[14] Richard Olsen, "Review of Visibility Factors in Roadway Signing," *Highway Research Board Special Report* 134 (1972), pp. 39-40.

[15] See W.G. Johnson, "Clutter is Out - Safety is In," *Traffic Safety* 67 (1967), pp. 10-13, 35-36.

[16] H.W. Case *et al*., "Analysis of Certain Variables Related to Sign Legibility," *Highway Research Board Bulletin* 60 (1952), pp. 44-58.

[17] R. Michaels and L. Cozan, "Perceptual and Field Factors Causing Lateral Displacement," *Highway Research Record* 25 (1963) pp. 1-13.

the generalizability of the results to more complex environments, although intuitively sound, is questionable. The limited sample size was also a problem with these studies.

Pollack hypothesized that the arrangement and size of buildings could serve as distractors. He correlated arterial streets in Chicago which vary in size of buildings and in the building setback (continuous versus modulated). The dependent variable was the number of front, rear, and fixed object accidents occurring mid-block which involved non-Chicago residents. He found (1) as the modulation of building height became increasingly chaotic, accidents increased; (2) if building setback was uniform but nevertheless close to the road, accidents increased; (3) if modulation of building setback was chaotic, accidents increased. Pollack concluded that the structure of the driver's visual field had direct impact on accident causation, that zoning ordinances for setbacks were not related to motorists' visual requirements, and that building setback should be carefully modulated.[18]

D. Within-Vehicle Distractors

Other distractors include those inside the automobile, although little research has been done on the distracting effects of driver activity. Dodds looked at driver-generated distractors, such as lighting or dropping a cigarette, setting a watch, and switching radio channels. Results indicated this type of distractions is a third-ranked cause among male students at Rutgers University involved in accidents.[19] A study by Brown looked at the effects of car music on driving behavior. The study was done on a limited number of subjects and cannot be considered conclusive. However, it is interesting to note that driver reaction time in heavy traffic was slow with music, and, as the pace of the music increased, so did the speed of the vehicle.[20]

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[18] L.S. Pollack, "Driver Distraction as Related to Physical Development Abutting Urban Streets," Master's thesis, Univ. of Illinois (1966).

[19] T. Dodds, "Minor Distractions Can Trigger Major Crashes," Traffic Safety 72, No. 12 (December 1972), pp. 28-29.

[20] I.D. Brown, "Effect of a Car Radio on Driving in Traffic," Ergonomics 8, No. 4 (1965), pp. 475-479.

E. Alternative Distraction Hypotheses

Some researchers have hypothesized that the number of stimuli in the environment which the driver must attend to creates an overload on the information processing system. This overload could create what Clayton terms a "failure to look,"[21] which more often than not results in an accident. Another explanation of driver distraction involves motivation, rather than perception, as a key factor. Summala and Naatanen suggest that motivation is more important than perception in determining a driver's ability to detect traffic signs.[22] When instructed to drive as safely as possible, drivers were able to detect and identify 97 percent of the signs in a designated area. The hypothesis did not hold up for the remaining percentage of unreported signs, however. These signs were almost always in areas of high distractor-density, making perception very difficult, if not impossible. It seems that, although motivation can encourage a greater awareness of the traffic information system, it falls short in areas of high distraction density (such as intersections). Schoonard and Gould investigated visual inspection accuracy of complex stimuli and concluded that studies of visual inspection will continue to have limited value until a cognitive theory of how people inspect is established.[23]

F. Evaluations and Conclusions

Although all of the above studies point to distraction as a cause of accidents, the evidence is inconclusive. Most of the studies used a limited number of subjects and so were unable to generalize across age, sex, or other variables. Possibly with more research utilizing larger samples of the population more conclusive evidence could be found. The studies were also unable to provide a causal link between the driver's behavior and the distraction. One main reason for this is that drivers involved in accidents are reluctant to admit they were distracted by the environment as this is tantamount to admitting liability.

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[21] Clayton, op. cit.

[22] Heikki Summala and Risto Näätänen, "Perception of Highway Traffic Signs and Motivation," Journal of Safety Research 6, No. 4 (1974), pp. 150-154.

[23] J.W. Schoonard and J.D. Gould, "Field of View and Target Uncertainty in Visual Search and Inspection," Human Factors 15, No. 1 (February 1973), pp. 33-42.

Most cities have ordinances regulating the extent to which advertising can distract a driver's attention, yet they are often couched in ambiguous terminology and are based on policy makers' hunches rather than on actual safety evidence. Contributing to a safer traffic environment by replacing intuitive reasoning with sound evidence should be the main objective of future research.

On the whole, it appears that there has been very little actual research on potential distractors in field settings. Most of the research that has been done was completed nearly two decades ago. Many of the results are equivocal (like those of billboard research) and based on either purely correlational data, or on data resulting from poorly designed field experiments. As a result, policy makers responsible for controlling roadside distraction have been left with very little hard data upon which to make their decisions.

II. VISUAL DISTRACTION IN THE TRAFFIC ENVIRONMENT

A. Public Signs and Lights: Overview

The AAA states that 70 percent of drivers surveyed consider inadequate signing to be the top ranking highway problem.[24] Bad signing may include signs so close to decision points that drivers cannot change lanes safely and signs that list small or distant towns but ignore major points nearby. They conclude that signs should list familiar names, in addition to the unfamiliar official designations.

Woods, Rowan, and Johnson used a diagnostic team approach to identify deficiencies in the present system of roadway delineation (signing and marking).[25] They evaluated visual discrimination on freeways, on urban-arterial streets, and on two-lane highways. They conclude that, on freeways, driver expectancies should be considered in signing. Drivers expect green backgrounds for freeway directional signing and overlook signs with different colored backgrounds. They suggest the use of diagrammatic signs for interchanges of difficult geometric design (e.g., cloverleaf). Specially designed signs, reflecting a highly consistent

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[24] New York Times (March 30, 1975).

[25] D.L. Woods, N.J. Rowan, and J.H. Johnson, A Summary Report: Significant Points from the Diagnostic Field Studies, Research Report 606-4 (College Station, TX: Texas Transportation Institute, Texas A&M Univ., 1970).

coding system, are recommended for easier identification of freeway signs. For two-lane highways, pavement markings were thought to be most important because drivers were more dependent on the view of the road for guidance.

Heathington, Worrall, and Hoff studied what types of information pertaining to congestion drivers preferred. The results of the questionnaire were that traffic information was preferred to no information. For heavy congestion, drivers preferred an accident warning to a speed guideline (e.g., "Accident ahead, heavy congestion next 3 miles" was preferred to "Speed 5 - 15 m.p.h. next 3 miles.")[26]

Woltman and Forbes, Snyder, and Pain have reviewed traffic signing literature since the 1930's.[27] They note the following important criteria for evaluating the effectiveness of signs: (1) legibility -- the maximum distance at which a sign can be read, and (2) attention or priority value -- the ability of a sign to stand out from its surroundings and attract the driver's attention. The variables most often found to affect legibility and attention value of signs are brightness contrast, color, shape, letters (size, width, spacing, and type), lateral displacement, number of signs, reading habits of drivers, and luminance. Woltman adds driver "mental set" to this list of variables.

Research on signs and traffic safety can be divided into two areas: (1) private signs and (2) public signs. Despite some research findings to the contrary, there is convincing evidence (such as the study by the Boston Redevelopment Authority, 1971) that private signs compete for the attention of the driver (and are thus distracting) and by sheer numbers hinder location of public (traffic) signs. The Boston Redevelopment Authority study suggests limits should be placed

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[26] K.W. Heathington, R.D. Worrall, and G.C. Hoff, "An Analysis of Driver Preferences for Alternative Visual Information Displays," Highway Research Record 303 (1970), pp. 12-16.

[27] H.L. Woltman, "Review of Visibility Factors in Roadway Signing," Highway Research Record Special Report 134 (1972), pp. 28-37; T.W. Forbes, T.E. Snyder, and R.F. Pain, "Traffic Sign Requirements: Review of Factors Involved, Previous Studies and Needed Research," Highway Research Record 70 (1965), pp. 48-56.

on the number and type of private signs allowed.[28] Some studies have shown that, for "landscaped" routes, private signs can be unpleasant, while, on "commercial" routes, the absence of stimuli other than the public signs can be dull and monotonous.[29]

Much data have been accumulated on public signs. Forbes et al. have shown that sign size and brightness do, of course, affect the speed at which a sign can be seen (not necessarily read) and have also shown that the contrast of the sign with its background and the contrast of letters with the rest of the sign are important. Forbes et al. showed that color did not have very much effect (exclusive of its brightness) on the ability to see signs but was useful for coding of information. Green signs (like those on interstate routes) were deemed the best for both day and night. Forbes and his colleagues' primary recommendation was that the background against which the sign would be seen should be considered in the sign's design.[30] Allen et al., in an article on illumination of signs, agree with Forbes that the letter-to-sign contrast is important but also point out that letter size and type have effects also. Allen et al. give approximate lighting requirements for various types of roads and backgrounds and point out that very bright signs may impair the driver's ability to readjust to darkness.[31] With respect to sign position, Forbes et al. report that overhead mounting was preferred by their subjects.[32] For signs placed at the side of the road, King has provided a formula for computing size and letter size demands. A distance of 10 degrees to the side of the road

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[28]Boston Redevelopment Authority, op. cit.

[29]G.H. Winkel, R. Malek, and P. Thiel, "Community Response to the Design Features of Roads: A Technique for Measurement," Highway Research Record 305 (1970) pp. 133-145.

[30]T.W. Forbes et al., "Letter and Sign Contrast, Brightness, and Size Effects on Visibility" and "Color Brightness in Simulated and Full Scale Traffic Sign Visibility." Highway Research Record 216 (1968), pp. 48-54 and pp. 53-65, respectively.

[31]T.M. Allen et al., "Luminance Requirements for Illuminated Signs," Highway Research Record 179 (1967), pp. 16-37.

[32]Forbes et al., "Color Brightness in Simulated and Full Scale Traffic Sign Visibility," op. cit.

is considered a maximum for placement at the side of the road, and King points out that increasing this angle may mislead drivers to expect the road to eventually come closer to the sign.[33] Increasing the angle would require increases in the letter size.

The major issue in traffic sign research is standardization. In 1969 it was estimated that only about 50 percent of U.S. signs complied with U.S. standards. The Boston study also points to a need for standardization and cites "fragmented authority" for putting up signs as a major part of the problem.[34] There is some movement towards adopting international signs (which are primarily symbols), but some difficulties exist (for example, some international signs are similar to U.S. signs of different meaning). Finally, methods for evaluating highway signs and for predicting sign visibility have been proposed.[35]

B. Field Studies of Specific Variables

1. Brightness Contrast

In a 1969 summary of earlier laboratory and field research, Forbes concludes that brightness contrast of signs is the most important element in determining both legibility and attention value of signs.[36] Through laboratory experimentation, he develops contrast equations for certain signs by which to calculate the distance at which these signs are later recognized in the field. Forbes found two kinds of contrast to be important: (1) contrast of the letters with the sign and (2) contrast of the whole sign with its natural background. From the field experiments he found a need for increased contrast between the legend and the sign when there is a high contrast between the sign and its

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[33] G.F. King, "Some Effects of Lateral Sign Displacement," Highway Research Record 325 (1970), pp. 15-29.

[34] Boston Redevelopment Authority, op. cit.

[35] V.D. Bhise, and T.H. Rockwell, Development of a Methodology for Evaluating Road Signs, (Columbus, OH: Department of Industrial and Systems Engineering, Ohio State Univ., 1973) and "Toward the Development of a Methodology for Evaluating Highway Signs Based on Driver Information Acquisition," Highway Research Record 440 (1973), pp. 38-56; Forbes et al., "Color Brightness in Simulated and Full Scale Traffic Sign Visibility," op. cit.

[36] Forbes, T.W., "Factors in Highway Sign Visibility" Traffic Engineering 39, No. 12 (September 1969), pp. 1-8 and 22-27.

background (such as the shaded side of a sign against a bright sunny background). When signs were equal in brightness contrast, chromatic, or hue, contrast was an added factor in their effectiveness. Thus, the contrast between the sign and its background is one of the most important determinants of a sign's visibility. Forbes has emphasized this factor in many of his studies.[37] Hansen and Woltman have done a normative study of the different backgrounds that signs are seen against (dark trees, 23.1 percent; sky, 19.1 percent; bridge, 15.8 percent, etc.).[38] Generally, the brighter a sign, the more easily it can be seen,[39] but this is not independent of the background. Allen _et al_. give the approximate lighting requirements for various types of roads and backgrounds and point out that very bright signs may impair a driver's ability to readjust to darkness.[40]

2. Color and Shape

In a field study of stop signs, Berren found color and shape to be more important than legend in sign effectiveness. He suggests the use of color coding for increasing the attention value of signs. Although black-legend-on-white-background signs have better legibility, Berren concludes that the difference in legibility between these and colored signs is not great enough to preclude the use of color, especially since color has the added advantage of increasing the attention value of signs.[41]

Decker compared legibility distances of different colored signs at three levels of illumination. He found no significant differences between colors in daylight conditions. At night, white letters on blue backgrounds were seen at significantly greater distances than green letters on white backgrounds for both

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[37] Forbes _et al_., "Color Brightness in Simulated and Full Scale Traffic Sign Visibility," _op. cit_. and "Letter and Sign Contrast, Brightness, and Size Effects on Visibility," _op. cit_.

[38] Douglass Hanson and Henry L. Woltman, "Sign Backgrounds and Angular Position," _Highway Research Record_ 170 (1967), pp. 82-96.

[39] Forbes _et al_., "Color Brightness in Simulated and Full Scale Traffic Sign Visibility," _op. cit_.

[40] Allen _et al_., "Luminance Requirements for Illuminated Signs," _op. cit_.

[41] F. Berren, "Safety on the Highway: A Problem of Vision, Visibility, and Color," _American Journal of Ophthalmology_ 43 (1957), p. 2.

of the two illuminated conditions - high and low headlight beams.[42]

The shape of a sign conveys its "class" (for example, warning signs as opposed to destination signs) at a greater distance than does the detailed meaning of the sign. Shape was also shown to be a better conveyer of sign information than color, although consistent shape/color combinations (e.g., red hexagon = stop) are often sufficient to carry the sign's meaning to the driver.[43] In a different vein, signs which are curved convey more information about which lane of traffic the sign is directed to than do flat signs.[44]

Several studies have examined the effectiveness of different colors, but the results are somewhat unclear. All studies seem to indicate that contrast between the sign and the legend is very important, but which two colors are best seems to vary from study to study,[45] and Forbes found no difference exclusive of brightness. Forbes has shown, however, that green highway signs provide the best all-around background contrast for both day and night.[46]

3. Letter Size and Shape

In a 1950 field study Forbes and Moscowitz compared legibility distances of signs with letter heights ranging from 5 to 18 inches, with two types of lettering (all upper case versus a combination of upper and lower case letters), and with legends of varying degrees of familiarity. They found increased legibility distances with an increase in letter size and in familiarity of legend for signs with both types of lettering. The increase due to familiarity was greater for signs with both upper and lower case letters. They conclude that the effectiveness of mixed letters for familiar names is due to the similarity to normal lexical patterns.[47]

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[42] J.D. Decker, "Highway Sign Studies - Virginia," Research Board Proceedings 40 (1960), pp. 593-609.

[43] Boston Redevelopment Authority, op. cit.

[44] C.J. Ladan, R.M. Heron and T.M. Nelson, "A Signal-Detection Evaluation of Flat vs. Curved Marker Performance," Perceptual and Motor Skills 39 (1974), pp. 355-358.

[45] Boston Redevelopment Authority, op. cit.

[46] Forbes et al., "Letter and Sign Contrast, Brightness, and Size Effects on Visibility," op. cit.

[47] T.W. Forbes and K. Moscowitz, "A Comparison of Lower Case and Capital Letters for Highway Signs," Proceedings, 30th Annual Meeting of the Highway Research Board, 1950, p. 255.

According to standard signing practices, 1 inch of letter provides 50 feet of visibility, and an optimum height/width ratio of 5/1 is best for the letters.[48] The relative effectiveness of upper and lower case letters has not been convincingly determined by the existing research. Increasing the space between letters increases legibility up to a point (one letter width). Rounded letters were shown to be superior in terms of legibility to block letters.[49]

4. Lateral Displacement

Greenshields suggests that the optimal lateral displacement of signs off the roadway should be 5 degrees to the left or right of the driver's forward visual axis, but, due to practical considerations, the maximum lateral displacement must be widened to 10 degrees to the left or right.[50]

In 1967 Hanson and Woltman conducted a field survey to measure the angular position of existing signs. Their route included 1560 miles of freeways in seven states with 4054 destination and distance signs. They found most of the signs on flat terrain to be within the 10 degrees limits suggested by Greenshields. However, in metropolitan and gently rolling terrain, 10 percent to 37 percent of the signs were located outside the range. They also found that, in mountainous terrain, 53 percent of shoulder-mounted signs and 29 percent of overhead signs were located outside the optimum displacement area, defined by them as $\pm$ 4 degrees vertical and $\pm$ 6 degrees horizontal.[51]

King has developed a formula for selecting letter signs for displaced signs on roadsides. The variables used in the formula include velocity of the car, displacement distance, the angle of regard of the driver (curved road or tangent situation), and the number of messages on the sign. In this study, the driver had from the time the sign became legible until it was outside his field of vision to read the sign. It was found that placement of signs immediately adjacent to the highway markedly increased reading time. King warns that lateral displacement of signs may cause special problems for night drivers because a

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[48] J.C.G. Conniff, "Danger: Signs Ahead," New York Times Magazine, Section 6 (March 30, 1975), pp. 32-36.

[49] Boston Redevelopment Authority, op. cit.

[50] B.D. Greenshields, Traffic Engineering Handbook (Washington, D.C.: Institute of Traffic Engineers, 1965).

[51] Hanson and Woltman, op. cit.

displaced sign may give the driver deceptive cues about the course of the road. He considers a 10 degree angle between the roadway and the driver's line of sight to the sign to be the maximum allowable lateral displacement for a road sign.[52] Forbes has stated that the overhead position is the best for highway signs.[53]

5. Driver Reading Habits

Forbes, in his early study "A Method for Analysis of the Effectiveness of Highway Signs," points to the fact that four out of five times, signs are read from top to bottom and from left to right. The number of words one can comfortably read in a single glance is only three or four.[54]

Johansson and Backlund performed a study which indicated that road signs were seen by one out of two people. In the experiment, a road sign, visible at 300 meters, was set up for the test. The passing cars were stopped at a police checkpoint, and drivers were asked seven questions ranging from "What was the last road sign?" to "Are you a professional driver?" In this experiment, the main result of the 1966 experiment was supported: road signs have a low signal value. The experiment also indicated that signs located above the highway were more likely to be seen than those located to either side.[55]

In a series of field studies, Bhise and Rockwell collected data on driver sign reading behavior with an eye marker camera system. The eye marker camera provided a continuous record of the driver's eye movements superimposed upon his view of the forward road scene (signs, traffic, and highway design). The purpose of the study was to help designers evaluate signs for their ability to provide the necessary information efficiently without interfering with other driving tasks.

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[52] G.F. King, op. cit.

[53] Forbes, "Factors in Highway Sign Visibility," op. cit.

[54] T.W. Forbes, "A Method for Analysis of the Effectiveness of Highway Signs," Journal of Applied Psychology 23 (1939), pp. 669-684.

[55] G. Johansson and F. Backlund, "Drivers and Road Signs," Ergonomics 13, No. 6 (1970), pp. 749-759.

Findings were:

(1) drivers do look at a majority of the freeway signs, although they spend more time viewing relevant ones;

(2) the driver spends more time viewing a sign when it omits the needed information than when it supplies the information;

(3) he starts to view signs relatively later when traffic is heavy;

(4) although less time is spent viewing a familiar sign than an unfamiliar one, the difference is small;

(5) drivers on a through course look to the left side of the road for signs while drivers wanting to exit attend to the right side;

(6) drivers sometimes take less time than they need to view a sign (compared with minimum viewing times found in lab studies).[56]

Mourant and Rockwell studied eye movement and its effects on driving. The experiment recorded eye movement on three trial runs on a highway. During the first trial, the subject was to become familiar with the road; in the second, he was to use whatever visual signs were needed in order to complete the trial; and, in the third, he was to complete the trial without using signs. During trial one, the subjects sampled a wide area in front of them, but by trial three, sampling was confined to a smaller area. Thus, the researchers concluded that route familiarity plays an important role in visual sampling strategies. The discussion concludes that peripheral vision is used to monitor many driving cues and that it is important to have clearly visible markers on our roads.[57]

6. Driver Mental Set

One field study pertaining to the "mental set" of the driver was found. Summala and Naatanen asked subjects to drive down a two-lane highway route with relatively heavy traffic (obeying all safety rules) and to name every traffic sign they saw. The researchers were seeking to demonstrate that motivation was more important than perception in the driver's ability to detect traffic signs. Ninety-seven percent of the signs over the whole route were reported. Almost all signs in the rural areas were detected, but in urban

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[56] Bhise and Rockwell, "Toward the Development of a Methodology for Evaluating Highway Signs Based on Driver Information Acquisition," op. cit.

[57] R.R. Mourant and T.H. Rockwell, "Mapping Eye Movement Patterns to the Visual Scene of Driving," Human Factors 12, No. 1 (February 1970) 1, pp. 81-87.

sections the percentage of unreported signs rose to 8.95 percent. The authors conclude that when motivated, drivers will see most signs, and they attribute the differences in percentages of signs reported to the signs' locations. The most frequently unreported signs were usually located at intersections and other difficult areas. Even when drivers were motivated, signs had to compete with other elements in the environment for driver attention.[58] In their review of signing literature, Forbes, Snyder, and Pain stress the importance of attention-gaining characteristics in the effectiveness of signs. They suggest that future research should emphasize priority value. While there is limited research in this area, they suggest that practical application of attention-gaining principles can be seen in the use of oversized stop signs.[59]

7. Delineation Systems

In an extensive study of sign delineation systems, Seguin and Hostetter attempt to evaluate the degree of resistance to "clutter" or "visual noise" of various delineation treatments of exit ramps, curves, lane drops, and stop approaches. All delineation systems showed a high degree of resistance to "clutter," but the study was confounded by various factors including learning. The results indicate that crystal post delineators were more vulnerable to the effects of clutter than amber delineators on curves. No differences were found for lane drop or stop approach situations. Painted gore marking resulted in better performance than raised pavement markers at exit ramps.[60]

8. Background

Only one study focusing on the background of signs was found. Hanson and Woltman recorded information on the backgrounds of 4054 destination and distance signs over a 1560-mile route in seven states. The most common background was dark trees (23 percent). Sky and bridges were the next most prevalent backgrounds. For metropolitan areas, sky was most frequent. For business areas, bridges and buildings were the most frequent sign backgrounds.[61]

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[58] Summala and Näätänen, op. cit.

[59] Forbes, Snyder, and Pain, op. cit.

[60] E.L. Seguin and R.S. Hostetter, "Roadway Delineation Systems: Coding and Information Value Study," National Cooperative Highway Research Program Report 130 (1972), pp. 190-206.

[61] Hanson and Woltman, op. cit.

In discussions of Woltman's review,[62] Forbes and Olsen both note the effects of "clutter" on sign effectiveness. Forbes suggests the use of serial signing rather than groups of signs to cut down on visual clutter.[63] Olsen suggests the use of an artificial background, such as a flat black screening, "to provide a break in the cluttered environment and increase the target value of a sign."[64]

All of the research focuses on characteristics of the sign itself. No field studies were found that evaluate the surrounding environment and attempt to determine which environmental factors contribute to or inhibit sign effectiveness.

III. ROAD GEOMETRY

Kihlberg and Tharp have prepared an excellent summary of the literature relating highway design elements to traffic accidents.[65] The following is a summary of the points brought out in their survey.

1. The greater the traffic volume of a facility, the higher the accident rate.
2. The number of lanes appears to have no relation to the accident rate. Multilane highways have accident rates comparable to those on two-lane highways with similar design standards.
3. Medians do reduce the number of head-on collisions. Guardrails may increase the accident rate while reducing the severity of accidents.
4. Access control is the major factor in reducing the number of accidents. However, access control is usually accompanied by high design standards, which also tend to reduce accident rates.
5. Curvature and accident rates are thought to be directly proportional: sharper curves have higher accident rates.
6. Gradients and accident rates are directly proportional: steeper grades have higher accident rates.

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[62] Woltman, "Review of Visibility Factors in Roadway Signing," op. cit.

[63] Forbes, "Review of Visibility Factors in Roadway Signing," op. cit.

[64] Olsen, "Review of Visibility Factors in Roadway Signing," op. cit.

[65] J.K. Kihlberg and K.J. Tharp, "Accident Rates as Related to Design Elements of Rural Highways," National Cooperative Highway Research Program Report 42 (1968).

7. Coincident curves and grades have higher accident rates.
8. Intersections have more accidents when the number of vehicles on the minor street increases. Increases in volume on the major facility do not affect accident rates at intersections.
9. Structures (bridges, overpasses, underpasses) which are the same width or narrower than the approach pavements have higher accident rates.

Kihlberg and Tharp maintain that "the major objective of highway and street design has been directed at handling traffic movement with the least possible delay and interference while safety considerations have received comparatively minor attention." In response to this perceived need for highway safety information, they conducted an extensive three-year study relating design elements of highways to accident rates. Research was divided into two parts: Phase I -- to determine accident and severity rates for various highway types, and Phase II -- to determine the relationship of accident and severity rates to particular geometric features of highways (curves, grades, intersections, and structures such as bridges, overpasses and underpasses).

Data were collected on accident and severity rates, traffic volume, and highway design features of specific areas from highway departments in 5 states for Phase I -- California, Louisiana, Oklahoma, Ohio, and Oregon -- and in 3 states for Phase II -- Ohio, Connecticut, and Florida.

The following is a summary of their findings for both phases:

1. Four-lane highways had higher accident rates than two-lane highways in the absence of medians and access control.
2. Access control had the most effect on accident reduction; partial control of access was partially effective.
3. Medians tended to decrease accidents, but the effect was not clear-cut.
4. The number of one-vehicle accidents decreased with increasing traffic volumes while multi-vehicle accidents increased with increasing average daily traffic.
5. The presence of gradients, curves, intersections, and structures increased accident rates. The effect was most marked for intersections and least for gradients. The simultaneous presence of several of these elements typically raised accident rates two or three times higher than rates on highway segments free of such interfering factors. Severity rates were not affected by geometric features.

Two other studies were found with results consistent with this last finding of Kihlberg and Tharp. Using a factor analysis technique on roadway and accident data, Versace found that accidents were more frequent in areas with more cars and where intersections and driveways interfered with traffic flow. He concludes that "there are more accidents at those places where the situation places greater demands on the momentary perceptual decision-motor capabilities of the driver."[66]

Head conducted a correlational study based on accidents and average daily traffic to examine the effect of certain roadway elements (commercial and residential units, driveways, intersections, signals, and posted speeds) on accident rates. His results were similar to those of Versace: accident rates increased with an increase in traffic and with increased number of intersections and other roadway elements.[67]

Signing and other highway delineations (e.g., pavement markings and post delineators) have generally been the methods suggested for improving safety of hazardous road geometry.

Taylor *et al*. conducted the most extensive research evaluating the effectiveness of specific delineation treatments at particular roadway situations.[68]

Woods, Rowan, and Johnson and Berger suggest the use of diagrammatic signs at unusual or confusing highway interchanges.[69]

A. Highways/Freeways

1. Landscape Architecture

Much of the landscape architecture research is oriented toward asethetics. Halprin suggests the use of parks and landscape design to screen urban freeways from the central city area and to make their appearance more palatable to city dwellers.[70]

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[66] Versace, *op. cit*.

[67] Head, *op. cit*.

[68] J.I. Taylor *et al*., "Roadway Delineation Systems," *National Cooperative Highway Research Program Report* 130 (1972).

[69] Woods, Rowan, and Johnson, *op. cit*.; and W.D. Berger, *Guidelines for Advanced Graphic Guide Signing* (Arlington, VA: Serendipity, Inc., 1970).

[70] "Urban Park and Fountains to Screen Freeway; Seattle, Washington," *American Institute of Architects Journal* 56, No. 3 (September 1971), pp. 53-54.

Other articles mention the use of landscape design to provide safety for motorists. They do not present empirical data but common-sense suggestions, for example, using shrubbery on divided highways to protect the driver from the glare of on-coming traffic lights.[71]

An early study presents a theory for the use of landscape design to help the driver read and anticipate possible danger areas on the highways. Grubbles suggests the theory of "road focus." He maintains that the driver normally focuses far ahead of his or her vehicle and anything that interferes with this distant road focus tends to "automatically reduce speed." He suggests the use of trees and shrubbery to highlight signs, to mark the outside edge of curves, and to create a "bottle neck" effect at the top of hills "to control unconsciously the turn of the wheel and the foot-pressure on the accelerator."[72]

But Noble complains that too much public money has been spent beautifying highways with trees which have later become traffic hazards. They grow out of control and obstruct the driver's view and can cause serious harm when vehicles run off the road and hit them.[73]

2. Curves

Only one study relating curves to accidents was found. McDonald and Ellis conducted a study to find a method by which a designer can determine whether a highway curve design will demand so much of a driver's attention that he will not be able to react quickly enough to avoid accidents. They determined the percentage of the driver's attention required to follow the lane while various curves were negotiated at different speeds.[74]

Most of the articles on curves deal with physical cues, such as the degree of angle and degree of grading necessary for a safe curve. Some give formulae for computing these angles. Other studies describe proper signing of curves.

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[71] Ernest T. Perkins, "Relationship of Accident rate to Highway Shoulder Width," Highway Research Board 151 (1957), pp. 13-14.

[72] J.L. Grubbles, "Texas Landscapes for Safety; The Psychologic Approach to Highway Planting," Landscape Architecture 30 (1940), pp. 59-63.

[73] C.M. Noble, "Highway Design and Construction Related to Traffic Operations and Safety," Traffic Quarterly 25 (1971) pp. 533-549.

[74] L.B. McDonald and N.C. Ellis, "Relationship between Predicted Stress and Measured Attentional Demand in a Simulated Driving Task," Human Factors Society (October 1974), pp. 117-122.

3. Medians

Properly designed, medians virtually eliminate head-on collisions. From the perspective of our project, the problem of medians is how to increase their visibility so that the driver does not run off the road onto the median or end up on the wrong side. Yu reviewed the literature on median visibility and concluded that the median should be visible and clearly delineated at all times, particularly at night.[75] Common factors found to reduce visibility are weather, on-coming headlight glare, topography, and median design (depressed). Among the remedies suggested for these problems are the use of delineators (reflectors, stripes, raised buttons, etc.), adequate signing to warn of divided roadway, slightly raised medians, and glare screens such as plants,[76] guardrails, and mesh screens.[77] A study near Philadelphia found mesh screens reduced night accidents by 23 percent.[78] Garner surveyed medians of varying widths on high speed facilities and found 30-40 feet to be the safest minimum width.[79]

4. Shoulders

Road shoulders can be either paved or unpaved, and are designed to provide an emergency parking or driving area. Unpaved shoulders share many of the problems of visibility mentioned above for medians -- particularly adequate delineation at night. Consequently, many of the same delineators are used. One report states that shoulders should be continuous with a usable width of from

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[75] J.C. Yu, "Median Visibility Improvements: Needs, Methods and Trends," Highway Research Record 366 (1971), pp. 92-101.

[76] J.W. Hutchinson and J.H. Lacis, "An Experiment with Evergreen Trees in Expressway Medians to Improve Roadway Delineation," Highway Research Record (1966), pp. 85-98.

[77] John T. Capelli, Research Report Number 13 (New York, NY: Department of Transportation, March 1973).

[78] "Glare Barrier Cuts Accident Rates," Public Works 106, No. 3 (March 1975), p. 89.

[79] G.R. Garner, "Accidents at Median Crossovers," Highway Research Record 312 (1970), pp. 55-63.

8 to 12 feet and should "obviously appear so to invite use in emergencies."[80] These conclusions were drawn more from common sense than from research. For paved shoulders, texture and color are considered good cues to help the driver delineate the road edge. Some shoulders are even grooved so that they "rumble." The only field research on road shoulders uncovered so far was a correlational study which concluded that there was no relationship between accident rates and shoulder width on Connecticut's highways.[81]

5. Ramps and Interchanges

Several good studies deal with the safety and visibility of highway interchanges and ramps. Van Wagoner and Wright and Baker present no empirical data, but stress the importance of geometrical design in aiding the driver to negotiate these decision-making areas with a minimum of confusion.[82] Noble also points to the importance of design in interchange spacing, ramps, and merging conditions.[83]

Lundy conducted a three-year study of 722 freeway ramps in California. His purpose was to determine which geometric features play important roles in ramp safety and to classify these features according to ramp type and relative safety. He found correlations between accident rates and ramp type, grades from access to freeway, fixed objects, and speed-change lane lengths.[84]

In a presentation of part of an on-going 11-year study of highway geometry by the California Highway Department, Gabriel asserts that "interchange geometry should be made as simple and easy to follow as possible."[85] He says that there

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[80] Perkins, op. cit.

[81] R.C. Gupta, and R.P. Jain, "Effect of Certain Roadway Characteristics on Accident Roads for Two-Lane, Two-Way Roads in Connecticut," Transportation Research Record 541 (1975), pp. 50-54.

[82] W.T. Van Wagoner, Highway Safety Design Practices: A Topical Review, 1970; and P.H. Wright and E.J. Baker, "Causes of Traffic Accidents," Traffic Engineering 43 (1973), pp. 41-43.

[83] Noble, op. cit.

[84] R.A. Lundy, "Effect of Ramp Type and Geometry on Accidents," Highway Research Record 163 (1967) pp. 80-117.

[85] J.D. Gabriel, "Wrong-Way Driving in California Freeways," Traffic Quarterly 28 (1974), pp. 227-240.

is convincing evidence that motorists use the roadway pavement as their primary guide. The California Highway Department uses observers with "wrong-way counters" (much like traffic counters) and photographs taken at the ramps to collect and verify their data. One hundred and fifty of these units have been set up and rotated to different ramp sites since May 1971.

Gabriel stresses the importance of visibility of exit ramps. He cites a study in 1965 that found that half of the wrong-way freeway accidents involving fatalities and injuries occurred where sighting distance was less than 1,200 feet.

He notes that some ramps are dangerous because they have an unusual or confusing design, such as left-hand exits: "Approximately 70 percent of the wrong-way off-ramp entries that resulted in accidents in recent years involved non-standard or unusual interchange types." Problem ramps of standard design are ususally those which present an "optical illusion" to the driver, such as a "phantom road" that causes the driver to turn too soon.

Taylor _et al_. studied nine ramp sites with different geometric designs.[86] They used observers to collect data and interviewed drivers in this before/after study. The observers were watching for particular "erratic maneuvers" (e.g., crossing gore area, stopping in gore, backing up, sudden slowing or lane change). Most of the interchanges had a total erratic maneuver rate of more than 1 percent of the total exiting and through-traffic volume, while no more than 0.20 percent is considered acceptable. Taylor and his colleagues maintain that sighting distance is "one of the most critical design parameters at freeway exits." They suggest that the sighting distance to gore areas be between 1,000 and 2,000 feet. They make further suggestions about proper interchange design based on their study areas (e.g., long, full-width, S-shaped deceleration lanes when sighting distance is necessarily restricted; sufficient distance between entrance and exit ramps, especially if they are on opposite sides of the highway, to prevent weaving of traffic; avoidance of all left hand and tangential ramps, i.e., ramps departing from the main line on a tangent while through-lanes curve to the left, when possible).

After the initial observations, signing and painted markings were used to

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[86] Taylor _et al_., _op_. _cit_.

correct and better delineate the ramp areas. Each of the nine sites was then evaluated individually, and it was found that the special markings did produce slower speeds at the exit areas and fewer erratic maneuvers and accidents.

B. Streets

1. Intersections

Compared to the literature available on interchanges, little has been done on intersections in the past few years. A good summary of several nationwide studies on intersection geometry was prepared by Box and Associates.[87] The studies indicate that intersectional accidents accounted for about 41 percent of the total number of accidents in urban areas and 27 percent in rural areas. The most common intersection configurations are L, Y, T, jog (offset), and cross-type. The geometry of an intersection is rarely looked at independently of its control elements (signs and signals) and the relative traffic volumes of the intersecting streets. For example, in studies on uncontrolled intersections, cross-type intersections were found to have from 14 to 41 times more accidents than T intersections in urban subdivisions, and 4 times the accident frequency of T or Y intersections in rural areas. This strongly suggests the advantage of using T intersections for local streets in both rural and urban areas. For correcting problems in already existing intersections, the most frequent solutions are the increased use of control signs or signals and the installation of left-turn lanes. Box and Associates cite studies from several states showing methods to be effective in reducing intersectional accident frequencies.

Perkins and Harris have developed a direct observation type of instrument to rate an intersection's accident potential, rather than relying solely on accident data.[88] Observers systematically record the number of impending accident situations (conflicts) and traffic violations during a set observation

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[87] Paul C. Box and Associates, "Intersections," Chapter 4 of Traffic Control & Roadway Elements - Their Relationship to Highway Safety/Revised (Washington, D.C.: Highway Users Federation for Safety and Mobility, 1970).

[88] S.R. Perkins and J.I. Harris, "Traffic Conflict Characteristics: Accident Potential at Intersections," Highway Research Record 225 (1968), pp. 35-41.

period. The categories of intersectional conflicts are: (1) left-turn, (2) weave (side swipe), (3) cross traffic, (4) red light, and (5) rear-end. This instrument was found to be sensitive to subsequent changes in intersection design at nearly 400 improved intersections and to correlate well with recorded accident rates at those intersections.[89]

2. Left-Turn Lanes

Little information on left-turn lanes that is directly relevant to our project has been found so far. Box and Associates cite a California study that indicated a significant decrease in accident frequency when left-turn lanes were installed at 40 unsignalized urban and rural intersections.[90] Many articles acknowledge the importance of providing lanes to make left turns off major routes. Ring and Carstens developed several formulae using factors such as number of lanes, time needed to complete turn, speed, volume, accident costs (direct and indirect) and construction costs to determine the benefit/cost ratio of installing left-turn lanes at specific intersections.[91]

3. Pavement Markings

The best method of pavement marking or delineation is raised traffic markers. They have been shown to be the most easily discernible (they produce warning noise when drivers move outside their lane) and can be made of a reflective material for better night visibility. They cannot be used in areas where snow-plows are operated. Utah has designed and tried a recessed or textured delineation to produce the same effect as raised markers. These recessed stripes, when painted, can be seen better at night than the conventional stripe, even when wet. The best design found for the recessed delineation has grooves cut 90 degrees to the flow of traffic.

Most highways lack adequate median visibility at night. Vehicles under delineated median conditions were operated significantly better than those under the nondelineated conditions. Proper road markings resulted in safer and more

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[89] W.T. Baker, "An Evaluation of the Traffic Conflicts Technique," Highway Research Record 384 (1972), pp. 1-8.

[90] Box and Associates, "Intersections," op. cit., p. 2.

[91] S.L. Ring and R.L. Carstens, "Guidelines for the Inclusion of Left-Turn Lanes at Rural Highway Intersections," Highway Research Record 371 (1971), pp. 64-75.

efficient traffic operation on divided highways but showed no effect on the speed of the vehicles observed. Research has been done on the use of colored sections of pavement to provide direction and guidance to drivers. They caused no speed decrease, resulted in more uniform patterns of lane changing than with painted islands, and had little or no effect on traffic flow patterns. Colored pavements are effective in channeling left-turning vehicles into left-turn lanes. Solid yellow lines have proven to be the best for indicating the direction of travel of adjacent lanes.

IV. PSYCHOLOGICAL PROCESSES IN NEGOTIATING THE TRAFFIC ENVIRONMENT

From a psychological point of view, the state-of-the-art of traffic research leaves much undetermined. As an aspect of the relationship between human beings and the environment, the interactions between people and automobiles have developed relatively recently. Judging from a large selection of references, it seems that most research on automobile drivers has not integrated the knowledge of psychological processes with the technical and functional research done on roadway and vehicular designs. Much research has been done on traffic-related issues, but these studies generally lack holistic views that would ensure realistic applications of the findings. Psychologists approach the topics of perception, cognition, information processing, and sensory psychophysics from widely divergent perspectives.

A. Perception

Most of the perceptual research carried out by psychologists has dealt primarily with "object" perception as opposed to the broader topic of "environmental" perception. Most theorizing about the nature of environmental perception is based on the findings of object perception studies and does not lend itself freely to a total understanding of the performance of the driver in the traffic environment. On the other hand, the "perceptual" research done by engineers and designers ranges from advanced mathematical calculations of visual fields to the evaluation of traffic signs. Some of the general conclusions reached by a sample of these perceptual studies will be given to suggest some of the topics involved.

One article concerning the visual fields of drivers concluded that, at normal speeds, features of the visual environment provide the most important aids for vehicular guidance.[92] For example, the roadway is used to obtain the scale of the terrain and the objects in it. The roadway boundaries and lane markings are used to align the moving vehicle with the road. But, for all the considerations covered in this article, nothing was mentioned about how the driver responds to these fields of vision to obtain a correct perception.

In a slightly different approach to perception, many studies have been made concerning the size, shape, and legibility requirements of traffic signs. One study has compared the feasibility of three different methods of evaluating signs.[93] The approaches used were: field experiments on highways under normal conditions; modified on-the-road measures using signs 1/3 their normal size viewed at 1/3 the speed of the first experiments; and lab studies. The experimenters monitored the distance at which the signs were correctly read. They found that performance was better for identifying warning signs than regulatory signs and that symbol signs were identified earlier than legend signs.

Another study using eight field experiments and three lab experiments concluded that drivers spend more time viewing signs with a relevant message; a driver spends more time viewing a sign when the information he or she needs is absent rather than present; and the driver tends to view the signs later when traffic is heavy.[94] Similarly, another lab study attempted to measure reaction time as an index of traffic sign perception and concluded that the reaction time was smaller for classifying than for identifying signs as being regulatory, warning, or informative.[95] Many of these experiments utilized eye-marker cameras and other devices to monitor eye movements. Still other studies dealt with the color and luminance requirements of traffic signs. One field study concluded that at night

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[92] R.W. Danielson, "The Relationship of Fields of Vision to Safety in Driving with a Report of 680 Drivers Examined by Various Screening Methods," American Ophthalmological Society Transactions 54 (1965), pp. 369-416.

[93] R.E. Dewar and J.G. Ells, "Comparison of Three Methods for Evaluating Traffic Signs," Transportation Research Record 503 (1974), pp. 38-41.

[94] Forbes, "Review of Visibility Factors in Roadway Signing," op. cit.

[95] R.E. Dewar, J.G. Ells, and G. Mundy, "Reaction Time as an Index of Traffic Sign Perception," Human Factors 18, No. 4 (August 1976), pp. 381-391.

white letters on blue background were read at a greater distance than green letters on a white background.[96] Another field study that attempted to determine the luminance requirements of signs at different levels of ambient illumination found that large bright signs will impair drivers' adaptation to darkness and vision for other low luminance objects beyond the sign.[97] The problem with most of these perceptual studies is their lack of generalizability to the real-world traffic environment due to their artificial testing methods.

B. Cognition

Currently, cognitive psychologists are exploring whether a person can perceive a given letter faster when it is in the context of a random set of letters or in the context of a word. Engineers are not conducting such studies, but the kind of studies they are conducting fall under the concept of "visual search."

One such study conducted by Mourant and Rockwell compared the visual processes of novice drivers to those of experienced drivers.[98] The subjects of the experiment drove a short test route while their visual movements were recorded. The results indicated that novice drivers performed far below experienced drivers in visual quickness and accuracy but improved after training. The experimenters suggest the need for novice drivers to develop skill in acquiring visual information before being allowed to drive on public roads.

One other study concerning the effects of visual search on driver performance was conducted using two methods. One method was to observe unknowing subjects and record their visual search times at an intersection. The other method was a simulation to measure the subject's reaction times in changing lanes, as well as his methods of visual search. The experimenters found that risk-levels in driving increased due to unnecessary, long visual searches and to the drivers' methods of search.[99] The implications are that improvements in highway and vehicle designs, which are important factors in the acquisiton of visual information, could also decrease risk in driving.

One further study that could conceivably fit in this category deals with a computer simulation of the visual requirements of drivers during left and

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[96] Decker, op. cit.

[97] Allen et al., "Luminance Requirements for Illuminated Signs," op. cit.

[98] R.R. Mourant and T.H. Rockwell, "Strategies of Visual Search by Novice and Experienced Drivers," Human Factors 14, No. 4 (August 1972), pp. 325-335.

[99] G.H. Robinson et al., "Visual Search by Automobile Drivers," Human Factors 14, No. 4 (August 1972), pp. 315-323.

right freeway-merging maneuvers.[100] The computer model used permits visual quality analysis of various individual on-ramp configurations by comparing visual success at selected points along the ramps. The conclusions of this study include:

(1) guardrails, obstructions, and short ramp lengths increase the probability that a driver will not see other vehicles when merging;
(2) these factors also decrease reaction/decision time necessary for safe merging;
(3) cockpit interference in left merges increases close to the ramp-highway intersections, and
(4) vision in left rearview mirrors during right merges is non-existent.

Finally the experimenters conclude that proper merge dilemma zones should be upstream, with 200-300 feet of unobstructed view.

C. Information Processing

The concept of "information processing," which is something of an extension of the first two categories, perception and cognition, is apparently defined in the same manner by psychologists and engineers. The definition assumes that an individual is a "single-channel device" upon which demands are made by various information sources in the environment. But it is also assumed that environments always provide more information than can possibly be processed, and questions of "channel-capacity" and "overload" must be considered. Unfortunately, no matter what kinds of investigations are being undertaken, the concept of "information processing" is still at a hypothetical level, and as yet there is no way to operationalize the term "overload."

In a paper entitled "Visual Manual Feedback Mechanism in Human Vehicular Performance," again the driver and the vehicle are considered a "dynamic closed-looped feedback regulated" system.[101] This paper approaches the kind of cybernetic viewpoint necessary in today's traffic research. The authors describe three levels of sensory feedback necessary for the driver's functional operation of the machine. These are: (1) <u>reactive feedback</u>, which represents signals the driver receives from self-generated body movements; (2) <u>instrumental feedback</u>,

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[100] P.H. Decabooter and K.C. Sinha, "Comparison Study by Computer Simulation of the Driver's Visual Park-Task During Left and Right Freeway Merging Maneuvers," <u>Highway Research Record</u> 388 (1972), pp. 1-12.

[101] H.S.R. Kao and M. Nagamachi, "Visual-Manual Feedback Mechanism in Human Vehicular Performance," <u>Ergonomics</u> 12, No. 5 (1969), pp. 741-751.

which is the information the driver receives concerning the action of the machine; and (3) operational feedback, which was found to be the most important aspect of efficient motion-regulation of performance. This level of sensory feedback is defined as the persisting "dynamic" effects of tool-using operations on objects, materials, and environmental situations.

That paper demonstrates that a driver does more than steer; he or she uses many kinds of information input to align the car with the road. Considering the human factors involved in automobile operation, the designs of vehicles and roads should be more responsive to the underlying motor and perceptual interactions.

The ultimate goal of information processing is to predict "workload," the amount of sensory input a driver can tolerate and still maintain control of the vehicle. This notion may be expanded to all aspects of the driving situation. One investigation has even considered the warranting of fixed roadway lighting by the amount of operator workload.[102] The authors supply formulae for the computation of "information demand," "information supply," and "warranting conditions," as well as other priorities. They conclude that when information demand exceeds information supply without roadway lighting in a given situation, then the roadway lighting is assumed to be necessary.

D. Sensory Psychophysics

Psychologists who are doing research in the sensory psychophysical area are presently dealing with the paths that information may take after entering the brain through the visual and auditory tracts. Many are currently dealing with masking level differences of sound waves when they enter the nervous system; lateral contrast effects in vision; and "binaural beats," which is also concerned with the processing of auditory information. Some of the areas that engineers are concerned with that might parallel psychologists' interests are: measuring the "spare" mental capacity of drivers; monitoring the effects of car radios on driver performance; relating visual conditions to driver attention demands; and the concept of "vigilance" in the traffic situation.

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102 N.E. Walton and C.J. Messer, "Warranting Fixed Roadway Lighting from a Consideration of Driver Work-Load," Transportation Research Record 502 (1974), pp. 9-21.

By giving the driver another task to work on while driving, one group of investigators attempted to measure the spare mental capacity of drivers. Apparently, when the driver demonstrated noticeable decrements in his driving performance, then he had exhausted what spare capacity he might have had.[103] Along those same lines, Brown found that driving with music increased speed of reaction in light traffic more than driving with speech alone. But, in heavy traffic, the reaction time with music was slower than with speech, which was not significantly different from that with silence.[104]

In an experiment using goggles that could be adjusted by the experimenter to three different densities, it was demonstrated that poor visual conditions increase attentional demand but that skilled drivers were less affected.[105] Again, this stresses the need for drivers trained in attention and information acquisition areas. The experiments dealing with "vigilance" might also come under this heading of sensory psychophysics. The definition of "vigilance" includes the monitoring of various information displays for the presence of faint or infrequent stimuli which might occur unpredictably. For these tasks, which include long periods of non-stimulation, subjects' reaction times and accuracy were the measures of vigilance. The purpose of these experiments was to investigate which perceptual processes might become less efficient over time. As might be assumed, the effect of irrelevant or distracting stimuli is hard to determine and is a direct function of the primary task, the arousal level, the nature of the distraction, and the past experiences of the driver. One investigator has stated that specifying the effects of learning, arousal, and the amount of time spent on the task is essential to clarifying the relevance of the vigilance model to driving tasks.[106]

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[103] I.D. Brown and E.C. Poulton, "Measuring the Spare Mental Capacity of Car Drivers by a Subsidiary Task," Ergonomics 4 (1961), pp. 35-40.

[104] I.D. Brown, op. cit.

[105] T.H. Rockwell, "Visual Requirements in Night Driving," NCHRPP 99 (1970).

[106] J. Boadle, "Vigilance and Simulated Night Driving," Ergonomics 19, No. 2 (March 1976), pp. 217-225.

Some investigators have considered a few psychophysiological aspects involved in actual driving conditions. By comparing two groups of drivers — one group with good driving records, the other with bad driving records — the investigators were able to determine differences in the drivers' heart-rates, galvanic skin response rates, lateral eye movements, and any reversals between brake, steering wheel, and accelerator.[107] It was found that the "bad" drivers had a higher G.S.R. and more accelerator reversals as well as brake responses. By discovering which factors "bad" drivers have in common, it may be possible to prevent many traffic accidents in the future.

One investigation of road-user errors and accidents was conducted by an interdisciplinary team consisting of a mechanical engineer, a surgeon, a traffic engineer, and a psychologist.[108] They sampled over 200 accidents. The first and largest error group, which accounted for 28 percent of the total number of human errors, was termed "failure to look." This occurred when the road-user failed to perceive the total amount of relevant sensory information available. The prime critical factor was the distraction of the road-user at the critical moment. The causes of the distraction varied widely and included sign posts, side roads, and other landmarks. The second error group, which accounted for 18 percent of the total errors, was termed "error of misperception." This occurred when the road-user scanned the relevant parts of the situation but failed to perceive the hazard within it correctly. "Incorrect set" was more important than "visual defect." Many of the errors occurred under unfavorable lighting conditions, in which the signs, markings, and design of the road created an ambiguous situation.

E. How Drivers View Signs

Under normal driving conditions, a driver fixates the majority of the highway signs he/she passes, although he/she spends more time viewing those signs relevant to his/her route. The actual reading of a sign is not necessarily

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[107] J.D. Brown and W.J. Huffman, "Psychophysiological Measures of Drivers Under Actual Driving Conditions," Journal of Safety Research 4, No. 4 (December 1972), pp. 172-178.

[108] Clayton, "Road-User Errors and Accident Causation," op. cit.

done all at once; drivers often timeshare a sign with other environmental elements. The amount of time actually spent reading a sign depends on:

(1) distance at first fixation,

(2) traffic density,

(3) type of information needed by the driver, and

(4) driver's familiarity with the highway.

Familiar signs generally require 20 percent less time than unfamiliar signs. Drivers spend more time viewing a sign when the needed information is absent than when it is present. When driving in heavy traffic, drivers spend less time (50 percent) viewing signs than in low-density traffic conditions. On unfamiliar roads or in confusing situations, drivers exhibit the following sign-viewing characteristics:

(1) late beginning of sign reading,

(2) concentrated attention on signs during time-sharing intervals, and

(3) late completion of sign reading.[109]

F. Summary

After reviewing the current literature in the general areas of perception, cognition, information processing (a currently popular approach to perception and cognition), sensory psychophysics, and motivation, we feel that the following statement accurately reflects the state-of-the-art in these various areas: Research in areas dealing with basic psychological processes seems to have little bearing on the attempt to understand the performance of the driver in the traffic environment.

Today, as was true 50 years ago, the overwhelming bulk of perceptual research has been carried out in the context of object perception rather than environmental perception. The current state of affairs has led one eminent perceptual psychologist to conclude that "the investigation of perception has lost the essential esthetic unity without which any pursuit leads to chaos, rather than resolution."[110] Indeed, nearly all studies purportedly

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[109]Bhise and Rockwell, Development of a Methodology for Evaluating Road Signs, op. cit.

[110]W. Ittelson, "Environmental Perception and Contemporary Perceptual Theory," in Environment and Cognition (New York: Seminar Press, 1973), p. 3.

dealing with environmental perception are nothing more than traditional object perception experiments.[111] Furthermore, most theorizing about the nature of environmental perception is based on the findings of object perception studies.

In his review of the current state of environmental perceptual theory, Ittelson notes that there is a dearth of research to support any aspect of the theory.[112] He goes on to outline current theory, a few characteristics of which are of interest. He notes that environments always provide more information than can possibly be processed. Thus questions of channel capacity and overload are inherent in environmental perception. However, mere quantity of information does not tell the whole story, as the environment always represents (usually simultaneously) instances of redundant, inadequate, ambiguous, conflicting, and contradictory information. On an intuitive level, one can hardly disagree with this statement. Unfortunately, the information processing approach to perception is still hypothetical; there is no way to operationalize the concept of overload.[113] The current focus of the information processing literature is the question of serial versus parallel processing, studied by presenting information (usually letters or numbers) tachistoscopically and measuring subjects' reaction time.

Ittelson also notes that the first level of response to the environment is affective. This direct emotional impact of the situation controls motivation expectation. This is a critical point, as the expectancy that is created largely defines the kinds of actions that are likely to occur. This would seem to have relevance to the study of the driver's experience of the traffic environment. A study conducted in Russia by Babkov found that sections of the road with high accident concentrationswere associated with rises in the driver's pulse and galvanic skin response rate. The graph showing the changes of G.S.R. along the road was similiar to the graph showing the changes of the safety coefficient along the road.[114] This might suggest that the most dangerous

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[111] See D. Lowenthal, ed., Environment Perception and Behavior, Department of Geography Research Paper No. 109 (Chicago: University of Chicago, 1967).

[112] Ittelson, op. cit.

[113] R.N. Haber, Information Processing Approaches to Visual Perception (New York: Holt, Rinehart, and Winston, 1969); and Donald A. Norman and David E. Rumelhart, in press.

[114] Cited by Ittelson, op. cit.

traffic situation is that in which the driver is unable to perceive the danger of the situation. If the danger is not perceived, the reticular system is not brought into play. Consequently, the driver's level of arousal is low, and his/her reactions to external stimuli will not be as rapid as they would have been had the arousal level been higher. It is assumed that a heightened arousal level serves as an early warning system for the driver.

Other areas of human experimental psychology have less relevance to our interests. As noted above, cognitive psychologists are currently studying whether a person can perceive a given letter faster when it is in the context of a random set of letters or in the context of a word. The field of sensory psychophysics is presently dealing with issues of masking level differences, lateral contrast effects in vision, and binaural beats. Motivation theory is currently going through radical changes, with cognitive and physiological (opponent-process theory) approaches dominating the field.

LABORATORY-BASED ANALYSIS

I. INTRODUCTION

The character of commercial development in many urban and suburban areas has resulted in a plethora of advertising signs, neon lights, and gaudy billboards amassed along the roadside environment. While some recent studies have attempted to evaluate the impact of such development from an essentially aesthetic perspective,[1] surprisingly little research has examined the relationship between this array of potential visual distractors in the roadside environment and traffic safety. An opportunity for such an investigation occurred when psychologists at the University of Texas at Austin were approached by the Texas Office of Traffic Safety to develop a study evaluating the effect of background visual distractors due to commercial development on human performance associated with traffic safety.

Very little inquiry has been directed toward visual distractors and traffic accidents in field settings, and those data that do exist are both contradictory and open to methodological criticism. Two studies have reported positive correlations between the presence of advertising devices and automobile accidents on multilane highways.[2] In addition, two studies have reported positive correlations between traffic accidents and the number of elements in the roadside environment, such as commercial establishments, intersections, driveways, and traffic signals.[3] Other evidence, however, has reported no

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[1]Boston Redevelopment Authority, City Signs and Lights (Boston, 1971); and G. Winkel, R. Malek, and P. Thiel, "Community Response to the Design Features of Roads: A Technique for Measurement," Highway Research Record 305 (1970), pp. 133-145.

[2]Madigan-Hyland, Inc., Signs and Accidents on New York State Thruway, report prepared for the New York State Thruway Authority, February 1963; and Minnesota Department of Highways, Minnesota Rural Trunk Highway Accident, Access Point, and Advertising Sign Study (Minneapolis: 1952).

[3]J.A. Head, "Predicting Traffic Accidents from Elements on Urban Extensions of State Highways," Highway Research Board Bulletin 208 (1959), pp. 45-63; and J. Versace, "Factor Analysis of Roadway and Accident Data," Highway Research Board Bulletin 240 (1960), pp. 24-32.

relationship between highway accidents and advertising signs.[4]

In contrast, while a large body of research in a controlled experimental format has examined perception of the target traffic stimulus, e.g., the color, size and lettering of road signs,[5] almost no inquiry has systematically investigated perception of the target traffic signal as a function of distractors in its environmental background. Thus, while traffic engineers possess considerable knowledge relevant to the construction of adequate traffic signs isolated from their environmental context, very little is known about how to evaluate features of the background environment which may contribute to or reduce road sign effectiveness. An exception is a recent laboratory study of distraction by irrelevant information, which lends partial support to the contention that such distractors reduce driving performance under high information load conditions.[6] In addition, Kahneman, Ben-Ishai, and Lotan afford some indirect evidence, utilizing a selective attention task with bus drivers, demonstrating an inverse correlation between task perfomance and traffic accident history.[7]

The purpose of the present study was to systematically examine the effect of manipulations, along a number of specific dimensions, in the background environment on reaction time in responding to a target traffic stimulus, using a controlled experimental simulation of a traffic environment. The dimensions of the background environment investigated were selected both on the basis of the results of the small number of available field studies and on the probability of affording applicable information to traffic engineers. The background dimensions studied were: (1) <u>number</u> of distractors, (2) <u>color</u> of distractors, and (3) <u>location</u> of distractors relative to the target stimulus.

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[4] J.C. McMonagle, "Traffic Accidents and Roadside Features," <u>Highway Research Board Bulletin</u> 55 (1952), pp. 38-48; and J.C. McMonagle, "The Effects of Roadside Features on Traffic Accidents," <u>Traffic Quarterly</u> 6, No. 2 (1952), pp. 228-243.

[5] T.W. Forbes, "Factors in Highway Sign Visibility," <u>Traffic Engineering</u> 39, No. 12 (1969), pp. 1-8 and 22-27; and T.W. Forbes, T.E. Snyder, and R.F. Pain, "Traffic Sign Requirements: Review of Factors Involved, Previous Studies and Needed Research," <u>Highway Research Record</u> 70 (1965), pp. 48-56.

[6] A.W. Johnston and B.L. Cole, "Investigations of Distraction by Irrelevant Information," <u>Australian Road Research</u> 6, No. 3 (1976), pp. 3-23.

[7] D. Kahneman, R. Ben-Ishai, and M. Lotan, "Relation of a Test of Attention to Road Accidents," <u>Journal of Applied Psychology</u> 58, No. 1 (1973), pp. 113-115.

Reaction time in responding to the target signal was selected as the response measure because it was assumed to relate to both attentional deficits and accident risk in real driving situations. A controlled experimental format was chosen to afford the type of unequivocal data previously lacking in this area of investigation. It was hypothesized that increasing numbers of distractors, greater similarity of color between distractors and target, and closer proximity of distractors to the target would all exert significant increases in reaction time.

II. METHOD

A. Subjects

Subjects were 56 Introductory Psychology students who fulfilled a course requirement by their participation in the study. The sample included 29 males and 27 females.

B. Apparatus

1. Target and Distractor Stimuli

The target traffic stimulus consisted of an octagonal 2-inch (5.08-cm) diagonal measure replica of a standard traffic stop sign with white lettering on a red background. The background distractors consisted of 1 3/4-inch (4.45-cm) square replicas of commercial signs with white lettering on solid backgrounds of five colors (red, orange, blue, green, and black). A different four-letter word was printed on each distracting sign; the words were identified by Kucera and Francis as having a moderately high English language occurrence.[8] The differential shapes of the target and distractors were chosen to simulate the situation in the actual traffic environment where a stop sign's octagonal shape is typically contrasted with rectangular commercial signs.

2. Visual Displays

The visual displays were constructed using photographic slides of the target in a number of contrasting distractor backgrounds. The field behind the target and distractors was pale blue, simulating the sky, against which

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[8] H. Kucera and W.N. Francis, Computational Analysis of Present-Day American English (Providence, RI: Brown University Press, 1967).

such stimuli are often perceived in the actual environment. The manipulations of the background environment were operationalized as follows:

(a) number of distractors - the numbers of distractors were 2, 4, 6, and 10;

(b) color of distractors - the color of the distractors was defined as the color of the sign's background and included either high similarity to the target (red), intermediate similarity (orange), or low similarity (cool colors, i.e., blue, green, or black). This dimension was varied by altering the color combinations of distractors as follow: all red, all orange, all cool, combined red and orange, combined red and cool, combined orange and cool;

(c) location of distractors - the locations of the distractors were either proximate to the target or distant from the target. The distinction between proximate and distant was operationalized by dividing the field into a 7 x 5 grid (not visible on the slides) of 2-inch (5.08-cm) squares. Under the proximate condition, no distractor was further than 4 1/2 inches (11.4 cm) from the target; distractors were randomly placed within this range. Under the distant condition, no distractor was closer than 4 1/2 inches (11.4 cm) to the target; distractors were randomly placed within this range.

Three distractor dimensions were crossed, resulting in a total of 48 distractor combinations.

3. Slide Presentation

The subject sat facing an 18-inch (45.72-cm) by 12-inch (30.48-cm) frosted glass panel approximately three feet (.91m) away on which stimulus slides were projected from behind by a Kodak Carousel slide projector. A PDP8 computer was used to coordinate the slide presentations and to measure and record reaction time in milliseconds to each presentation. A table immediately in front of the subject held a console (connected to the PDP8) with two buttons, labeled either "stop" or "go".

C. Procedure

Subjects were tested singly. Each subject was presented a sequence of 106 slides. The slides consisted of 48 pairs of distractor combinations; in each pair, the target stop sign was present in one of the slides and absent in the other. In addition, ten initial practice slides were presented to familiarize the subject with the equipment. Following the ten practice slides, the order of presentation for the slides was randomized. The following verbal instructions were presented to each subject:

> You will see a series of slides on the screen in front of you. While all of the slides will contain some square signs, some slides will contain, in addition, a replica of an ordinary traffic stop sign. If a stop sign is present, press the button on your left [right] with your left [right] forefinger. If no stop sign is present, press the button on your right [left] with your right [left] forefinger. You are to react as quickly as you can, while also attempting to avoid mistakes.

Subjects responded using the forefingers of their right and left hands. For half of the subjects the "stop" button was placed on the right, and for half of the subjects it was placed on the left. Each slide remained on the glass panel until either the subject responded or 1.5 seconds had elapsed. A one-second intertrial interval preceded the presentation of the next slide. Errors were eliminated from the analysis. (Errors constituted only two percent of responses, and their pattern approximated the reaction time curve of correct responses.)

III. RESULTS AND DISCUSSION

Table 1 presents the results of a 4 by 6 by 2 analysis of variance (number by color by location) with reaction time as the dependent variable.* These results strongly support the proposed hypotheses. Number, color, and location showed statistically significant ($\alpha = .01$) main effects, with increasing number of distractors, greater similarity in color between distractors and target, and closer proximity of distractors to target all demonstrating positive relationships to reaction time. In addition, all two-way and three-way interactions were statistically significant.

Mean reaction times for the number dimension were: 587.56 ms. (2), 588.84 ms. (4), 611.38 ms. (6), and 616.28 ms. (10). Interestingly, this curve reflects a nonlinear function, with a step-wise increase in reaction time occurring between 4 and 6 distractors. For the color dimension, mean reaction times in order of increasing magnitude were: all orange: 581.65 ms., combination of orange and cool: 595.06 ms., all cool: 600.72 ms., combination of red and cool: 602.07 ms., all red: 612.04 ms., and combination of

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*The analysis is limited to the slide presentations where the stop sign target was present. A separate analysis of the slides where the target was absent revealed a similar pattern of responses.

TABLE 1

SUMMARY OF THREE-FACTOR ANALYSIS OF VARIANCE
(NUMBER OF DISTRACTORS X COLOR X LOCATION)
WITH REACTION TIME AS DEPENDENT VARIABLE

SOURCE	df	F	p
A (Number)	3	14.63	.0001
B (Color)	5	6.26	.0001
C (Location)	1	52.00	.0001
A x B	15	9.93	.0001
A x C	3	5.57	.0012
B x C	5	5.47	.0002
A x B x C	15	9.57	.0001

red and orange: 614.57 ms. Although this effect is complex, the dominant factor affecting reaction time is the presence of at least some red distractors. Mean reaction times for the location dimension were: distant: 586.93 ms. and proximate: 615.10 ms.

The two-way interactions between the background dimensions were especially interesting. Table 2 shows mean reaction times for number by location and color by location. All proximate distractors yielded high reaction times, while distant distractors reflected differential effects due to both number and color of distractors. Table 3 shows mean reaction times for number by color. While this interaction is complex, it appears that when some red distractors are present, reaction times are highly independent of the number of distractors, while with no red distractors, reaction time varies as a function of number of distractors.

Based on these interactional findings, it is possible to offer some speculation concerning underlying psychological processes that may have mediated the effects of background distractors on reaction time in this study. The overwhelmingly strong effect due to proximity indicates that the dominant process was the subject's inability to discriminate figure (target stop signal) from ground (array of background distractors). The failure of either number or color to appreciably affect reaction time in the proximate condition suggests that the subject perceived this figure-ground separation as a gestalt and that he/she did not perform a sequential screening of each distracting element. In contrast, the strong effects due to both number and color under the distant arrangement may indicate that here the subject reverted to an alternative process involving a visual scanning of the discrete distracting elements.

In light of these results, a number of practical suggestions may be offered to traffic engineers concerned with minimizing the potential negative effects of background distractors in the traffic environment. Most importantly, the present findings underscore the need for the traffic engineer to accept broader legislative and engineering responsibility for the total traffic environment, including both the public roadway and the contingent environment context. In general, such feedback falls under two areas of application: (1) the establishment of appropriate ordinances to legislatively limit the effect of distractors and (2) engineering decisions involving design changes in the target signal oriented toward counteracting the potential negative effects of background distractors.

TABLE 2

MEAN REACTION TIMES
FOR NUMBER AND COLOR OF DISTRACTORS
BROKEN DOWN BY LOCATION

LOCATION	NUMBER			
	2	4	6	10
Distant	564.16	568.23	605.13	610.21
Proximate	610.97	609.46	617.64	622.35

	COLOR					
	All Orange	Orange & Cool	All Cool	Red & Cool	All Red	Red & Orange
Distant	556.85	579.66	573.19	587.96	609.27	614.67
Proximate	606.45	610.47	628.25	616.18	614.81	614.46

TABLE 3

MEAN REACTION TIMES FOR NUMBER OF DISTRACTORS
BROKEN DOWN BY COLOR

NUMBER	COLOR	
	No Red Distractors	Some Red Distractors
2	563.60	611.53
4	582.32	595.37
6	618.35	604.41
10	605.63	626.93

The particularly strong effects in the present study relating to figure-ground discrimination suggest that the location of distractors relative to the target signal is of paramount importance. Any number or color of distractors located proximally to the target is likely to reduce the driver's ability to effectively discriminate a target traffic device. Where proximate distractors cannot be legislatively restricted, a wider range of engineering alternatives may be needed to counteract their potentially serious effects. Such developments might involve designing larger or brighter target signals or employing neutral background shields to more effectively contrast the target with its surrounding context.

Clearly, the present study represents only a first step in a complex area of investigation. We must exercise caution in generalizing these findings from a controlled laboratory environment to problems of roadside distractors in the natural environment. Further research is needed to demonstrate that the type of differences in reaction time found here relate to actual traffic accidents. The following chapter describes a field study designed to investigate the relationship between roadside signs and accidents in the actual traffic environment.

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FIELD-BASED ANALYSIS

I. INTRODUCTION

The purpose of the present study was to systematically investigate the relationship between signs located proximally to urban traffic intersections and the number of traffic accidents at those intersections. Based on the results of the small number of available field studies and a desire to afford applicable information to traffic engineers, signs were categorized along a number of specific dimensions. These dimensions included: total number of signs, type of sign (public versus commercial), size of sign, and color of sign. It was predicted that increasing numbers of signs, larger size of signs, and greater similarity of color between signs and target traffic device would all relate positively to number of traffic accidents.

II. METHOD

A. Selection of Intersections

Sixty intersections were randomly selected from a list of intersections within the City of Austin having at least one accident during the 1975 calendar year. To control for extraneous variables, several criteria were used to restrict the sample. Only cross-type intersections, where two through streets intersected at a 90° angle, were examined. The sample was also restricted to intersections having a recent 24-hour traffic count of between 5,000 and 30,000 vehicles, thus eliminating intersections with very high or very low traffic flows. The final sample was composed of intersections that showed a range of from 1 to 29 accidents during the 1975 calendar year, with the distribution skewed toward the upper end.

B. Instrument

A data sheet was developed to classify every sign observable at an intersection along three dimensions -- type of sign, size, and dominant color. Type was categorized as public or private. Public signs were defined as signs erected by a governmental entity, such as street signs, restricted parking signs, bus stop signs, and bike lane signs. Private signs were defined as signs erected by a nongovernmental entity, including those on store-fronts or in store windows. Signs were also categorized into two sizes.

Small signs were defined as signs whose size was equal to or smaller than a standard stop sign; large signs were those larger than a stop sign. In addition, signs were categorized as red or non-red according to their dominant color. Red signs were defined as those having a red or partially red background regardless of the letter color, or having any red letters or figures on a neutral background of white, black, brown, or clear (glass). All other signs were defined as non-red.

C. Dependent Variable

The number of at-fault accidents attributed to drivers approaching from each direction was computed for each of the 60 intersections for the 1975 calendar year. The accident data were available from the Urban Transportation Office and were derived from the reports of investigating police officers. For every accident, the data listed the direction of the vehicles involved, time of day, probable cause, and responsible party. Accidents occurring at night when signs were not clearly visible were excluded from the count, as were accidents apparently not related to distraction -- e.g., driving while intoxicated or speeding. Remaining at-fault accidents were due primarily to drivers failing to yield the right of way or ignoring stop signs.

D. Procedure

Three undergraduate psychology students collected the data for the study. The data collection procedure involved an observer standing at the righthand curb and facing the intersection and recording first at a point 200 feet (61.0 meters) from the cross-street. Every sign visible from that observation point was classified along the three dimensions. The observer then advanced to a point 50 feet (15.2 meters) from the cross-street and recorded any additional signs which could then be seen but were not visible from the first observation point. The procedure was repeated for each of the other approaches to the intersections. (For a one-way street, observations were recorded only along the direction that vehicles traveled on the street.) All observations were conducted in the summer of 1976, during the day under good light conditions. The undergraduate observers received training from a skilled observer who served as a criterion observer. The sample intersections were observed only after each observer had achieved 90 percent agreement with the criterion observer. Periodic inter-rater reliability checks were conducted between each observer and the criterion observer throughout the study. Average agreement was 92 percent.

III. RESULTS AND DISCUSSION

Table 4 shows the number of signs under each distractor dimension observed at high and low at-fault accident intersection approaches for both traffic signal controlled and stop sign controlled intersection approaches. For the traffic signal approaches, low accidents was defined as one or fewer annual accidents and high accidents as two or more annual accidents. For the stop sign approaches, low accidents was defined as zero annual accidents and high accidents as one or more annual accidents. For all distractor dimensions, the number of signs at high at-fault accident intersection approaches exceeded the number of signs at low accident intersection approaches.

Table 5 shows the zero-order correlation between each distractor dimension and at-fault accidents for both traffic signal controlled and stop sign controlled intersection approaches. For traffic signal approaches, no distractor dimensions demonstrated a significant relationship with at-fault accidents. For stop sign intersections, in contrast, three distractor dimensions (total signs, large signs, and non-red signs) demonstrated a significant positive relationship with at-fault accidents.

A problem in interpreting the data in Table 5 is the possibility that the positive relationship between number of signs and traffic accidents may reflect a positive correlation between both of these variables and rate of traffic flow. To discount the possible confounding influence of traffic flow, the data were reanalyzed controlling statistically for the influence of traffic flow. Table 6 shows the partial correlations, controlling for rate of traffic flow, between each distractor dimension and at-fault accidents for both traffic signal controlled and stop sign controlled intersection approaches. For all distractor dimensions, especially for traffic signal approaches, the partial correlations are somewhat weaker than the zero-order correlations, indicating that part of the relationship between signs and accidents is explained by traffic flow. Nevertheless, under the stop sign approaches, total signs and non-red signs remain statistically significant, and large signs shows a very strong statistical trend ($p = .058$).

A particularly strong picture of the relationship between signs and traffic accidents emerges when we examine separately the sample of stop sign approaches showing two or more annual accidents, controlling again for the effect of traffic flow. Table 7 shows the partial correlations, controlling for rate of traffic flow, between each distractor dimension and at-fault accidents for stop sign controlled approaches showing two or more annual

TABLE 4

MEAN NUMBER OF SIGNS UNDER EACH DISTRACTOR DIMENSION AT HIGH AND LOW AT-FAULT ACCIDENT INTERSECTION APPROACHES FOR TRAFFIC SIGNAL AND STOP SIGN INTERSECTION APPROACHES

	Type of Approach			
	Traffic Signal		Stop Sign	
Distractor Dimensions	Low Accidents (n=79)	High Accidents (n=66)	Low Accidents (n=26)	High Accidents (n=33)
Total Signs	17.78	25.85	3.46	10.39
Public Signs	7.38	9.74	1.85	6.61
Private Signs	11.53	18.18	2.19	3.88
Large Signs	11.21	15.71	1.04	3.33
Small Signs	10.43	13.59	3.23	7.18
Red Signs	7.86	11.62	1.46	3.82
Non-Red Signs	13.85	17.74	2.85	6.70

TABLE 5

ZERO-ORDER CORRELATIONS BETWEEN DISTRACTOR DIMENSIONS AND AT-FAULT ACCIDENTS AT TRAFFIC SIGNAL AND STOP SIGN INTERSECTION APPROACHES

Distractor Dimensions	Type of Approach					
	Traffic Signal			Stop Sign		
	r	df	p	r	df	p
Total Signs	.10	115	.131	.23	57	.040
Public Signs	.09	115	.171	.17	57	.100
Private Signs	.09	115	.175	.14	57	.140
Large Signs	.10	115	.137	.22	57	.047
Small Signs	.07	115	.214	.15	57	.131
Red Signs	.12	115	.107	.13	57	.170
Non-Red Signs	.07	115	.219	.23	57	.043

TABLE 6

PARTIAL CORRELATIONS CONTROLLING FOR TRAFFIC FLOW BETWEEN DISTRACTOR DIMENSIONS AND AT-FAULT ACCIDENTS AT TRAFFIC SIGNAL AND STOP SIGN INTERSECTION APPROACHES

Distractor Dimensions	Type of Approach					
	Traffic Signal			Stop Sign		
	r	df	p	r	df	p
Total Signs	.00	114	.495	.21	56	.050
Public Signs	-.07	114	.214	.16	56	.122
Private Signs	.02	114	.424	.14	56	.156
Large Signs	-.01	114	.478	.21	56	.058
Small Signs	.00	114	.481	.14	56	.155
Red Signs	.05	114	.308	.11	56	.212
Non-Red Signs	-.04	114	.335	.22	56	.050

TABLE 7

PARTIAL CORRELATIONS CONTROLLING FOR TRAFFIC FLOW BETWEEN DISTRACTOR DIMENSIONS AND AT-FAULT ACCIDENTS AT STOP SIGN INTERSECTION APPROACHES SHOWING TWO OR MORE ACCIDENTS

Distractor Dimensions	*r*	df	*p*
Total Signs	.45	15	.033
Public Signs	.11	15	.337
Private Signs	.50	15	.020
Large Signs	.59	15	.006
Small Signs	.24	15	.175
Red Signs	.07	15	.400
Non-Red Signs	.58	15	.008

accidents. Four distractor dimensions (total signs, private signs, large signs, and non-red signs) demonstrated a strongly significant positive relationship with at-fault accidents.

Based on these findings, a summary picture of the relationship between distracting signs in the roadside environment and traffic accidents can be presented. First, there is no evidence that signs present a traffic safety problem at intersections controlled by traffic signals. There is, however, evidence that signs are related to accidents at stop sign controlled intersections. The relationship between signs and accidents is especially strong at stop sign controlled intersections characterized by a relatively high number of accidents. In addition, the type of signs most strongly related to accidents at stop sign intersections is larger sized commercial signs. The relationship between non-red signs and accidents probably reflects both the influences of a diversity of colors in the distractor and the higher number of non-red signs in the environment.

The differential effects of signs on traffic signals and stop signs are probably due to a number of factors. Most important is probably the fact that, in the case of stop signs, distractors and target are of the same medium, while, with traffic signals, the media differ. Also, for most of the sites investigated, the placement of signals and stop signs relative to distractors differed. While all stop signs were placed at the right-hand curb, almost all traffic signals were placed at mid-road on an extension arm. Thus, stop signs and distractors tended to be located together proximally in the visual field, while traffic signals tended to be located more distantly from distractors in the visual field. Based on this interpretation, we might speculate that neon lights in the roadside environment would present a more serious distractor than signs at traffic signal intersections.

The findings of the field study described in this chapter are consistent with the results of the laboratory study described in the preceding chapter: both point to the need for legislation to restrict the number and size of commercial signs located proximally to stop signs and for design changes in the target signal to counteract the potential negative effects of background distractors. When legislative or design alternatives are not feasible, traffic signals rather than stop signs should be employed at sites where a significant number of commercial distractors are present.

THEORETICAL PREDICTIVE MODEL

Based on (1) theoretical analysis of existing traffic research knowledge, (2) results of the present laboratory-based analysis, and (3)those of the present field-based analysis, the following theoretical model may be postulated to relate traffic accidents to environmental visual distractors. The functions representing the contribution of the distractor dimensions are ordered to reflect their relative weights in the model:

$$TA = C + f_1(N) + f_2(P) + f_3(S) + f_4(R) + I + E$$

Where:

TA = yearly at-fault traffic accidents at stop sign intersection;

C = constant representing a base yearly accident rate;

N = number of commercial signs visible at the intersection;

P = average visual angle between target (stop sign) and the distractors (commercial signs);

S = average visual area of the distractors (commercial signs);

R = proportion of red signs at the intersection;

I = contribution from interactions between distractor dimension (N,P,S, and R); and

E = contribution from variables extraneous to the present analysis (e.g., driver, vehicle, and road characteristics).

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RECOMMENDATIONS FOR FURTHER RESEARCH

Based on the findings of the present project, recommendations may be advanced concerning the need for further research oriented toward understanding the relationship between roadside distractors and traffic accidents. First, a particularly important unanswered question concerns the relationship between lighted commercial distractors and traffic accidents in dark or dusk conditions. Second, the potential practical value of findings such as those generated in the present project for practicing traffic engineers and specialists needs to be assessed.

A field-based feasibility study is needed in which specific characteristics of night traffic accidents can be related to the type and number of lighted commercial distractors at a range of intersections. Such an analysis is essential to completing the knowledge base of psychological information concerning the relationship of commercial distractors to traffic accidents initiated in the present project. The present data indicate that commercial signs demonstrate an important relationship to traffic accidents at intersections controlled by stop signs. The question of whether and to what extent lighted commercial distractors may bear a relationship to night accidents at intersections controlled by traffic signals remains an important unanswered question. This knowledge is essential to developing a complete picture of the potential relationship between the range of types of commercial distractors encountered in the contemporary roadside environment and traffic accidents.

In addition, a detailed study is needed concerned with the important issue of how to maximize the utilization of scientific knowledge in the traffic safety field by agencies responsible for implementation of traffic safety standards at the local level. The manner in which scientific knowledge is summarized, condensed, and presented to policy-oriented agencies is as important a concern as the initial generation of the knowledge. For, if available scientific knowledge is not distilled and packaged in a form that is meaningful and useful to decision makers, the original scientific merit of the knowledge is of little relevance. The rigor, care, and precision of the scientific attitude needs to be addressed with a careful evaluation of how best to achieve a complete utilization on the part of society of relevant scientific knowledge. Such a project should include three distinct phases: (1) a compilation and distillation of existing psychological knowledge concerning commercial distractors and traffic accidents in a form readily accessible to decision makers in appropriate city agencies; (2) facilitation through a series of collaborative work sessions of the utilization of the psychological knowledge by city agencies; and (3) a follow-up evaluation of the level of success achieved in the actual utilization of the existing knowledge by city agencies. Such information will be of use to the Office of Traffic Safety not only in regard to the present area of concern, but also in assessing more broadly the potential practical utility of other similar knowledge gained through related project endeavors.

PSYCHOLOGICAL ANALYSIS OF DEGREE OF
************* ******** ** ****** **
SAFETY IN TRAFFIC ENVIRONMENTAL DESIGN
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ABSTRACTS
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LUMINENCE REQUIREMENTS FOR ILLUMINATED SIGNS.
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THE PURPOSE OF THIS EXPERIMENT IS TO DETERMINE LUMINENCE REQUIREMENTS OF SIGNS AT DIFFERENT LEVELS OF AMBIENT ILLUMINATION.

A FIELD METHOD WAS USED WITH INTERNALLY ILLUNINATED SIGNS OF DARK ON BRIGHT AND BRIGHT ON DARK BACKGROUNDS. LUMINANCE VALUES RANGING FROM .2 - 2,000 FT-L WITH AND WITHOUT HEAD LIGHT GLARE AND WITH THREE LEVELS OF AMBIENT ILLUMINATION. THE DEPENDENT VARIABLE WAS LEGIBILITY DISTANCE.

LEGIBILITY DISTANCE IS AFFECTED BY HEADLIGHT GLARE AND COMPETING ILLUMINATION. AVERAGE LEGIBILITY DISTANCES WERE 40 - 60 FT/IN. OF LETTER HEIGHT IN 2 TO 20 FT-L. BUT WERE 12 - 65 FT/IN. IN HIGH GLARE, HIGH AMBIENT ILLUMINATION CONDITION. THEY RECOMMENDED 10 FT-L FOR LOW LUMINANCE AREAS AND 100 FT-L FOR LIGHTED AREAS.

ALSO REPORTED WAS THAT A LARGE, BRIGHT SIGN WILL IMPAIR DRIVERS DARK ADAPTATION AND VISION FOR LOW LUMINANCE OBJECTS BEYOND THE SIGN.

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ALLEN, T.M., AND STRAUB, A.L.
SIGN BRIGHTNESS AND LEGIBILITY.
HIGHWAY RESEARCH BOARD BULLETIN, 1955, NO. 127, PP. 1-14.

THE PURPOSE OF THIS EXPERIMENT WAS TO STUDY THE EFFECT OF BACKGROUND ILLUMINATION ON THE LEGIBILITY OF REFLECTORIZED SIGNS.

THE METHOD WAS A FIELD STUDY, OF ONE SIGN AT FOUR LEVELS OF REFLECTANCE WITH 2 CONDITIONS OF BACKROUND ILLUMINATION: RURAL HIGH ILLUMINATION - STREET LIGHT, LIGHTED BUILDINGS, PARKED CAR GIVING HEADLIGHT BEAM; OPEN ROAD - NO BACKGROUND ILLUMINATION, ONLY LIGHTS OF TEST CAR. THE DEPENDENT VARIABLE WAS THE DISTANCE AT WHICH SIGNS COULD BE READ CORRECTLY.

RESULTS:

1) ILLUMINATION OF BACKGROUND DID HAVE AN EFFECT ON LEGIBILITY.
2) THERE WAS IRRADIATION EFFECT IN OPEN ROAD SITUATIONS. HIGH REFLECTORIZATION OF SIGNS CAUSED WHITE AREAS OF SIGN TO SPILL OVER TO BLACK. THE HIGH REFLECTANCE SIGN WAS READ AT GREATER DISTANCE WITH LOW BEAMS THAN WITH HIGH.
3) THE SUBJECTS ROAD AS PASSENGERS RATHER THAN DRIVER≠S AND THE CAR WAS MOVING AT ONLY 10 MPH.

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BHISE, V.D., AND ROCKWELL, T.H.
DEVELOPMENT OF A METHODOLOGY FOR EVALUATING ROAD SIGNS.
OHIO STATE UNIVERSITY, COLOMBUS, DEPART OF INDUSTRIAL AND SYSTEMS ENGINEERING, 1973.

THIS PAPER REPORTS THE RESULTS OF 11 STUDIES ON A WIDE RANGE OF TOPICS CONCERNING SIGNS.

BOTH LAB AND FIELD METHODOLOGIES WERE USED, BUT EMPHASIS WAS ON THE USE OF AN EYE-MARKER CAMERA.

THE RESULTS AND CONCLUSIONS, IF VALID WILL BE USEFUL TO BOTH THE LAB AND FIELD STUDIES.

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BHISE, V.D., AND ROCKWELL, T.H.
TOWARD THE DEVELOPMENT OF A METHODOLOGY FOR EVALUATING HIGHWAY SIGNS BASED ON DRIVER INFORMATION ACQUISITION.
HIGHWAY RESEARCH RECORD, NO. 440, 1973, PP. 38-56.

THE PURPOSE OF THE STUDY WAS TO STUDY THE DRIVER≠S SIGN READING BEHAVIOR TO ENABLE DESIGNERS TO EVALUATE SIGNS ON THE BASIS OF THEIR ABILITY TO MATCH THIS SIGN READING BEHAVIOR AND PROVIDE THE NECESSARY INFORMATION TO THE DRIVER QUICKLY AND EFFICENTLY WITHOUT INTERFERING WITH OTHER DRIVER TASKS. HE ALSO LOOKS AT HOW CHARACTERISTICS OF THE HIGHWAY AND TRAFFIC SITUATION AFFECT SIGN READING.

ELEVEN STUDIES WERE CARRIED OUT OVER A 3 YEAR PERIOD. IN THE EIGHT FIELD STUDIES, DATA WAS COLLECTED WITH AN EYE-MARKER CONTROL SYSTEM WHICH PROVIDES CONTINUOUS RECORDS OF THE DRIVER≠S EYE MOVEMENTS SUPERIMPOSID ON THE DRIVER≠S VIEW OF THE FORWARD ROAD SCENE (SIGNS, TRAFFIC, HIGHWAY DESIGN). SUBJECTS WERE ASKED TO DRIVE DOWN A SPECIFIC HIGHWAY AND EXIT AT A PARTICULAR PLACE. DATA WAS COLLECTED ON OVER 400 SIGNS.

THREE LAB STUDIES WERE CONDUCTED TO RELATE SIGN READING UNDER CONTROLLED CONDITIONS TO THE SAME SIGNS STUDIED IN THE FIELD STUDIES.

RESULTS:

1) DRIVER≠S SPEND MORE TIME VIEWING SIGNS WHOSE MESSAGE IS RELEVANT, BUT NON RELEVANT SIGNS ARE ALSO FIXIATED. DRIVER≠S DO LOOK AT THE MAJORITY OF FREEWAY SIGNS.
2) THE DRIVER SPENDS MORE TIME VIEWING A SIGN WHEN THE INFORMATION HE NEEDS IS ABSENT RATHER THAN THERE.
3) DRIVER TENDS TO VIEW THE SIGNS LATER WHEN TRAFFIC IS HEAVY.
4) DRIVER≠S SPEND LESS TIME VIEWING FAMILIAR SIGNS RATHER THAN UNFAMILIAR, BUT THE DIFFERENCE IS SLIGHT.
5) DRIVER≠S CONTINUING DOWN THE HIGHWAY LOOK AT SIGNS TO THE LEFT, WHEREAS DRIVER≠S EXITING LOOK TO THE RIGHT.
6) DRIVER SOMETIMES TAKES LESS TIME NEEDED TO VIEW SIGNS (AS COMPARED WITH LAB TIMES).

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BOADLE, J.
VIGILANCE AND SIMULATED NIGHT DRIVING.
ERGONOMICS, VOL. 19, NO. 2, MARCH 1976, PP. 217-225.

THIS PAPER DISCUSSES A STUDY DESIGNED TO INVESTIGATE THE RELATIVE CHANGES IN VIGILANCE, DRIVING SKILL, AND ARROUSAL LEVELS, IN THE CONTEXT OF A SIMULATED DRIVING TASK. THIS WORK WAS TO FURTHER EXPLAIN THE CHANGES THAT OCCUR IN MONOTONOUS CONDITIONS WHEN A PERSON IS ASKED TO RESPOND TO AN INFREQUENTLY OCCURING SIGNAL. THE DRIVERS TASK WAS TO FOLLOW ANOTHER CAR APPARENTLY MOVING AHEAD OF HIM ON THE ROAD. DURING THE TWO-HOUR SESSIONS, THE MEASURES OF PHYSIOLOGICAL AROUSAL DATA CHOSEN WERE: HEART RATE AND RESPIRATION RATE. A VIGILANCE TASK (MONITORING AND RESPONDING SURE AND NOT SURE TO LIGHTS) WAS INCLUDED AS A SECOND MEASURE OF AROUSAL, AND TO PROVIDE COMPARISONS WITH OTHER STUDIES WHICH HAVE USED SUBSIDIARY TASKS WHILE DRIVING.

THE RESULTS OF THIS INVESTIGATION SHOWED THAT THE PERFORMANCE ON THE VIGILANCE TASK WAS MORE STABLE OVER TIME THAN THE DRIVING TASK. CONTRARY TO OTHER STUDIES, THERE WERE CHANGES NOTED IN DRIVING PERFORMANCES NOT VIGILANCE PERFORMANCES. THESE DIFFERENCES MAY BE DUE TO THE LACK OF DANGER EVOLVED IN THE SIMULATOR. POOR PERFORMANCE OCCURED IN TWO PERIODS: AT THE BEGINNING AND AT THE VERY END OF THE SESSIONS. EXPERIMENTERS NOTE THAT INVESTIGATIONS ON STRESS MAY SUPPORT A POSSIBILITY OF A NON-LINEAR RELATIONSHIP BETWEEN AROUSAL AND VIGILANCE. SPECIFYING THE EFFECTS OF LEARNING, AROUSAL, AND THE AMOUNT OF TIME SPENT ON THE TASK IS ESSENTIAL TO CLARIFY THE RELEVANCE OF THE VIGILANCE MODEL TO DRIVING TASKS.

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BROWN, B., AND MONK, T.H.
THE EFFECT OF LOCAL TARGET SURROUND AND WHOLE BACKGROUND CONSTRAINT ON VISUAL SEARCH TIMES.
HUMAN FACTORS, VOL. 17, NO. 1, FEB 1975, PP. 81-88.

IN THIS STUDY THE EXPERIMENTERS LOOKED AT TWO ASPECTS OF APPLIED VISUAL SEARCH TASKS: 1) IS SEARCH PERFORMANCE AFFECTED BY NON-TARGETS WHICH ARE POSITIONED DIRECTLY ADJACENT TO THE TARGET≥ AND, 2) IS SEARCH TIME AFFECTED BY THE DEGREE OF CONSTRAINT (GROUPING VS. LOOSE ORGANIZATION) IMPOSED≥

TWO TYPES OF BACKGROUNDS WERE USED FOR THE SEARCH TASKS. ONE HAD A CONSTRAINED BACKGROUND WITH NON-TARGETS LOCALIZED IN THE PARTICULAR AREAS OF THE DISPLAY. THE OTHER DISPLAY UTILIZED AN UNCONSTRAINED BACKGROUND. THESE BACKGROUNDS WERE ON COMPUTER-GENERATED DISPLAYS UNDER SEVERAL CONDITIONS OF TARGET SURROUND. TWO EXPERIMENTS WERE RUN. ONE IN WHICH THE TARGET WAS BRIGHTER THAN THE NON-TARGETS. THE OTHER (A CONTROL FOR BRIGHTNESS) USED TWO NON-TARGETS IN CLOSE PROXIMITY OF EQUAL BRIGHTNESS AS THE TARGET.

THE PROCEDURE INVOLVED HAVING THE SUBJECT SIT BEFORE AN OSCILLOSCOPE SCREEN AT A CERTAIN DISTANCE AWAY. A WARNING TONE WOULD SOUND TO SIGNIFY A TRIAL. THE SUBJECT WAS INSTRUCTED TO PRESS A KEY TO VIEW THE DISPLAY AND SEARCH FOR THE TARGET. WHEN HE DISCOVERED THE TARGET, HE WAS TO RELEASE THE KEY. THIS ISOLATES THE TARGET AND HIS SEARCH TIME IS RECORDED. LASTLY, HE MUST PLACE THE DOT USING POTENTIOMETERS IN APPROX. THE FORMER POSITION OF THE TARGET. FOUR NAIVE SUBJECTS WERE USED IN EACH OF THE 2 EXPERIMENTS WHICH INVOLVED 200 SEARCH TRIALS OVER 10 CONDITIONS IN 3 SESSIONS PRECEDED BY 40 PRACTICE TRIALS.

RESULTS:

1) THE FREQUENCY DISTRUBUTIONS OF SEARCH TIMES FOR BOTH EXPERIMENTS WERE HIGHLY POSITIVELY SKEWED.
2) THERE WERE MORE ERRORS ON THE UNCONSTRAINED BACKGROUND SEARCHES AND THOSE WITH TARGET SURROUNDS C AND D.
3) THE LONGER SEARCH TIME A SEARCH TASK WARRANTED, THE MORE ERRORS WERE MADE. LONGER SEARCH TIMES WERE ASSOCIATED WITH THE DENSITY OF THE NON-TARGETS.

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BROWN, I.D.
EFFECT OF A CAR RADIO ON DRIVING IN TRAFFIC.
ERGONOMICS, VOL. 8, NO. 4, 1965, PP. 475-479.

THIS ARTICLE DEALT WITH THE EFFECTS ON DRIVER PERFORMANCE OF LISTENING TO A RADIO, VERSES DRIVING IN SILENCE.

BROWN USED A STAFF OF THE APPLIED PSYCHOLOGY RESEARCH UNIT AS SUBJECTS, 7 MALES, AND 1 FEMALE. THE CONDITIONS ALL SUBJECTS WERE IN WERE DRIVING IN SILENCE, WITH MUSIC, OR WITH A SPEECH, AND THE VARIABLES BEING HEAVY OR LIGHT TRAFFIC. HE MEASURED THE REACTION TIME OF EACH SUBJECT IN EACH CONDITION FOR VARIOUS DRIVING MOVEMENTS.

BROWN FOUND THAT DRIVING WITH SPEECH AND MORE SO WITH MUSIC, REDUCED REACTION TIME IN LIGHT TRAFFIC, BUT IN HEAVY TRAFFIC THE REACTION TIME FOR MUSIC WAS SLOWER THAN SPEECH, WHICH WAS NOT SIGNIFICANTLY DIFFERENT FROM SILENCE, WHEREAS MUSIC WAS.

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BROWN, I.D., AND POULTON, E.C.
MEASURING THE SPARE MENTAL CAPACITY OF CAR DRIVERS BY A SUBSIDIARY TASK.
ERGONOMICS, VOL. 4, 1961, PP. 35-40.

THEY USED A NEWLY DEVELOPED AUDITORY NUMBER TASK TECHNIQUE TO MEASURE THE DRIVER≠S SPARE MENTAL CAPACITY.

SHOWED DIFFERENCES BETWEEN A RESIDENTIAL AND A SHOPPING AREA.

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BROWN, J.D. AND HUFFMAN, W.J.
PSYCHOPHYSIOLOGICAL MEASURES OF DRIVERS UNDER ACTUAL DRIVING CONDITIONS. JOURNAL OF SAFETY RESEARCH, VOL. 4, NO. 4, DECEMBER, 1972, PP. 172-178.

THIS ARTICLE CONSIDERS SIX RESPONSES OF GOOD AND BAD DRIVERS IN FOUR DIFFERENT TRAFFIC SITUATIONS

BROWN AND HUFFMAN USED TWO GROUPS OF SIXTEEN SUBJECTS EACH. ONE GROUP HAD BAD DRIVING RECORDS, THE OTHER HAD CLEAN DRIVING RECORDS FOR THE PREVIOUS FOUR YEARS. RESPONSES MEASURED WERE HEART RATE, GSR, LATERAL EYE MOVEMENT, AND BRAKE, STEERING WHEEL, AND ACCELERATOR REVERSALS. ALL SUBJECTS DROVE AT BOTH DAY AND NIGHT IN ALL FOUR TRAFFIC CONDITIONS: RESIDENTIAL DRIVING, TWO-LANE RURAL DRIVING, FOUR-LANE EXPRESSWAY DRIVING, AND FOUR-LANE BUSINESS DRIVING.

RESULTS:

1) BAD DRIVERS HAD A HIGHER GSR, AND MORE ACCELERATOR REVERSALS AND BRAKE RESPONSES.
2) AT NIGHT, DRIVERS HAD LESS LATERAL EYE MOVEMENT AND A LOWER GSR: THEY HAD MORE ACCELERATOR AND STEERING WHEEL REVERSALS.
3) LATERAL EYE MOVEMENT AND BRAKE REVERSALS DIFFERED SIGNIFICANTLY IN ALL TRAFFIC CONDITIONS; HIGHEST IN RESIDENTIAL DRIVING AND LESSENING PROGRESSIVELY IN BUSINESS, EXPRESSWAY, AND RURAL DRIVING. GSR HAD A SIGNIFICANTLY LOWER MEAN LEVEL IN RURAL TRAFFIC. ACCELERATOR REVERSALS WERE MORE FREQUENT IN RESIDENTIAL DRIVING, WHILE STEERING WHEEL REVERSALS WERE SIGNIFICANTLY HIGHER ON RURAL HIGHWAYS, AND TO A LESSER EXTENT, HIGHER ON EXPRESSWAYS. HEARTRATE WAS NOT AFFECTED BY TRAFFIC CONDITIONS.
4) THOSE SUBJECTS WHO DROVE DURING THE DAY FIRST HAD A HIGHER HEARTRATE AND LOWER GSR THAN THOSE WHO DROVE FIRST AT NIGHT.

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CHILDS, J.M.
SIGNAL COMPLEXITY, RESPONSE COMPLEXITY AND SIGNAL SPECIFICATION IN VIGILANCE.
HUMAN FACTORS, VOL. 19, NO. 2, APR 1976, PP. 149-160.

THIS STUDY INVESTIGATES SIGNAL SPECIFICATION VS. UNSPECIFICATION AND THE INTERACTIVE PROPERTIES OF THESE WITH SIGNAL AND RESPONSE COMPLEXITY. THE EXPERIMENTERS WERE ESPECIALLY INTERESTED IN SEEING IF THE COMPLEXITY OF THE TASK WOULD CAUSE PERFORMANCE TO DETERIORATE RELATIVE TO SIMPLE TASKS.

64 MALE AND FEMALE PSYCHOLOGY STUDENTS WERE RANDOMLY PLACED INTO 8 TREATMENT GROUPS (SIGNAL COMPLEXITY, RESPONSE COMPLEXITY, SIGNAL SPECIFICATION AND 5 GROUPS MEASURING WITHIN-MEASURE LEVEL OF TIME). AN AUDITORY TASK WAS GIVEN WHICH CONSISTED OF A 50 MIN TAPED SERIES OF RANDOMLY PRESENTED NUMBERS AS THE NONSIGNAL EVENTS AS WELL AS FOR THE SIGNAL EVENTS. THE DEPENDENT VARIABLES WERE CORRECT DETECTION PERCENTAGE AND FALSE ALARM COMMISSION. ONE SIGNAL WAS GIVEN EVERY TWO SECONDS FOR A TOTAL OF 1,500 EVENTS.

RESULTS:

1) PERFORMANCE IN THE SIMPLE SIGNAL DETECTION TASK WAS SUPERIOR TO THAT IN ANY COMPLEX SIGNAL TASK.
2) THE DECREMENT IN PERFORMANCE WAS STEEPER ACROSS TIME FOR COMPLEX REACTIONS.
3) LOWER OVERALL DETECTION RATES IN COMPLEX TASKS WERE POSSIBLY DUE TO THE UNEXPECTEDNESS OF THE SIGNALS.
4) THERE WAS AN ABSENCE OF SIGNIFICANT SIGNAL COMPLEXITY BY SIGNAL SPECIFICATION INTERACTION FOR CORRECT DETECTION PERCENTAGE.
5) RATES OF FALSE ALARM COMMISSION DECREASED MARKEDLY OVER TIME WITH THE MOST OCCURING IN THE FIRST 30 MIN OF THE TASK.
6) WITHIN-SUBJECT VARIABILITY REMAINED STABLE.
7) THE MORE COMPLEX THE SIGNAL DETECTION TASK WAS AND ALSO IF UNSPECIFIED; THE MORE FALSE ALARMS WERE NOTED.
8) THE APPLICABILITY TO APPLIED MONITORING ENVIRONMENT IS THAT THE UNSPECIFIED SIGNAL CONDITION EXHIBITED CONSISTENTLY LOWER DETECTION PERCENTAGES, A HIGHER RATE OF FALSE ALARM, AND THE GREATEST NUMBER OF TOTAL ERRORS AS OPPOSED TO THE SPECIFIED SIGNAL CONDITION.

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CHRIST, RICHARD E.
REVIEW AND ANALYSIS OF COLOR CODING RESEARCH FOR VISUAL DISPLAYS.
HUMAN FACTORS, VOL. 16, NO. 6, DEC 1975, PP. 542-570.

IN THIS ARTICLE, THE AUTHOR REVIEWED THE EXPERIMENTAL LITERATURE ON THE EFFECTS OF COLOR ON VISUAL SEARCH AND IDENTIFICATION PERFORMANCE. THE AUTHOR WANTED TO EVALUATE THE BASIS OF POSSIBLE DESIGN RECOMMENDATIONS FOR OR AGAINST THE USE OF COLOR IN AIRCRAFT DISPLAYS. ONLY STUDIES SINCE 1950 WERE INCLUDED.

RESULTS:

1) COLOR IS SUPERIOR TO SIZE, BRIGHTNESS AND SHAPE, AND IDENTIFICATION INCREASED AS TASK DIFFICULTY INCREASED.
2) IDENTIFICATION ACCURACY IN UNIDIMENSIONAL COLOR DISPLAYS WAS INFERIOR TO DISPLAYS VARYING ONLY IN DIGITS OR LETTERS.
3) COLOR WAS CLEARLY INFERIOR TO LETTERS AND DIGITS IN A UNIDIMENSIONAL DISPLAY WHILE IN A MULTIDIMENSIONAL COLOR AND ALPHANUMERIC SYMBOLS WERE EQUIVOCAL IN IDENTIFICATION ACCURACY.
4) COLOR IN A MULTIDIMENSIONAL DISPLAY INTERFERED WITH THE CORRECT IDENTIFICATION OF ACHROMATIC ATTRIBUTES IN THE DISPLAY, AND INTERFERENCE INCREASED AS THE NO. OF COLOR DID.
5) THE ADDITION OF A COMPLETELY REDUNDANT COLOR TO SIZE, BRIGHTNESS AND AN ALREADY REDUNDANT COMBINATION OF BOTH FACILITATED ABSOLUTE IDENTIFICATION PERFORMANCE.

IF COLOR OF A TARGET IS UNIQUE FOR THAT TARGET AND IS KNOWN IN ADVANCE, COLOR AIDS IDENTIFICATION AND SEARCHING. IN A DISPLAY LESS TIME IS REQUIRED TO LOCATE OR COUNT COLORS. COLOR USED IN LESS TIME IS REQUIRED TO LOCATE OR COUNT COLORS. COLOR USED IN A PICTORIAL DISPLAY TO PROVIDE A NATURAL REPRESENTATION OF THE REAL WORLD DECREASES SEARCH TIME.

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CLAYTON, A.B.
ROAD-USER ERRORS AND ACCIDENT CAUSATION.
INTERNATIONAL CONGRESS OF APPLIED PSYCHOLOGY, 17TH, 25-30 JULY 1971, LIEGE, BELGIUM.

THIS WAS AN ON-THE-SPOT STUDY OF ROAD ACCIDENTS IN WORCESTERSHIRE BY AN INTERDISCIPLINARY TEAM OF A MECHANICAL ENGINEER, A SURGEON, A TRAFFIC ENGINEER, AND A PSYCHOLOGIST. THEY SAMPLED 210 ACCIDENTS.

THE FIRST AND LARGEST ERROR GROUP, WHICH ACCOUNTED FOR 28% OF THE TOTAL HUMAN ERRORS MADE WAS TERMED FAILURE TO LOOK. IT OCCURED WHEN THE ROAD USER FAILED TO PERCEIVE THE TOTAL AMOUNT OF RELEVANT SENSORY INFORMATION AVAILABLE TO HIM. THE PRIME CRITICAL FACTOR WAS THE DISTRACTION OF THE ROAD USER AT THE CRITICAL MOMENT. THE CAUSES OF THE DISTRACTION VARIED WIDELY AND INCLUDED SIGN POSTS, SIDE ROADS AND OTHER LAND MARKS.

THE SECOND ERROR GROUP, WHICH ACCOUNTED FOR 18% OF THE TOTAL ERRORS MADE WERE TERMED ERROR OF MISPERCEPTION. IT OCCURED WHEN THE ROAD USER SCANNED THE RELEVANT PARTS OF THE SITUATION BUT FAILED TO PERCEIVE THE HAZZARD WITHIN IT CORRECTLY. INCORRECT SET WAS MORE IMPORTANT THAN VISUAL DEFECT. MANY OF THE ERRORS OCCURED UNDER UNFAVORABLE LIGHTING CONDITIONS IN WHERE THE SIGNS, MARKINGS, AND DESIGN OF THE ROAD HAD CREATED AN AMBIGUOUS SITUATION.

RESULTS:

1) NON REDUNDANT COLORS RELATIVE TO NONREDUNCANT ACHROMATIC ACHROMATIC CODES, THE COLOR IS SUPERIOR TO SIZE, BUT INFERIOR TO ALPHANUMERIC SYMBOLS.
2) IDENTIFICATION ACCURACY IN UNIDIMENSIONAL COLOR DISPLAYS SUPERIOR RELATIVE TO IDENTIFICATION.

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COLE, B.L., AND BROWN, B.
SPECIFICATION OF ROAD TRAFFIC SIGNAL LIGHT INTENSITY.
HUMAN FACTORS, JUNE 1968.

THE PAPER ATTEMPTS TO PROVIDE DATA FOR THE SPECIFICATION OF TRAFFIC SIGNAL LIGHT INTENSITY BY EXTENDING THE EXISTING DATA TO INCLUDE SEVERAL SIGNAL SIZES AND SEVERAL BACKGROUND LUMINANCES. SUBJECTS FOLLOWED AN IRREGULARLY OSSILATING TARGET WITH A STEERING WHEEL. ERRORS IN THE TASK WERE RECORDED BUT WERE NOT A PART OF THE ANALYSIS. A RED LIGHT APPEARED AND SUBJECTS WERE ASKED TO STOP THE CAR BY REMOVING THEIR FOOT FROM THE ACCELERATOR. ABOVE 2.7 SECONDS REACTION TIME IT WAS CONSIDERED THAT THE LIGHT WAS UNSEEN. SIGNALS APPEARED AT IRREGULAR TIME INTERVALS. IN EVERY TRIAL OF FIFTY EXPOSURES, THERE WERE TEN SIGNAL INTENSITIES AND FIVE EXPOSURES OF EACH. THE RANGE OF INTENSITIES WAS SHIFTED, DEPENDING ON SIZE OR BACKGROUNG LUMINANCE UNDER THE TEST. SMALLER SIGNALS WILL BE MORE EFFECTIVE THAN LARGER ONES OF THE SAME INTENSITY IF BOTH THEIR INTENSITIES ARE LESS THAN OPTIMUM.

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CONNIFF, J.C.G.
DANGER: SIGNS AHEAD.
NEW YORK TIMES MAGAZINE, MARCH 30, 1975, SECTION 6, PP. 32-36.

THE AAA STATES THAT 70% OF DRIVERS CONSIDER LOUSY SIGNING TO BE THE TOP-RANKING HIGHWAY PROBLEM. SOME TYPES OF BAD SIGNING INCLUDE: 1) SIGNS TOO CLOSE TO DECISION POINTS SO THAT DRIVES CANNOT CHANGE LANES SAFELY; 2) SIGNS THAT LIST SMALL, DISTANT TOWNS OR GEOGRAPHICAL AREAS WHERE NOBODY SEEMS TO BE GOING, BUT IGNORE MAJOR POINTS NEARBY; 3) SIGNS THAT DO NOT LIST FAMILIAR NAMES, BUT USE UNFAMILIAR OFFICIAL DESIGNATION (LIKE I-87); 4) SIGNS HUNG IN LOLLIPOP CLUSTERS SO DRIVERS MOVING AT NORMAL SPEED DO NOT HAVE TIME TO SORT OUT THOSE RELEVANT TO HIM.

AN EXAMPLE OF A CONFUSING SIGN: EAST-NORT-WEST HIGHWAY MEANS YOU GO EAST ON N.W. HIGHWAY.

STANDARD SIGNING PRACTICES: 1 INCH/50 FT DISTANCE, RATION OF 5/1 HEIGHT TO WIDTH - YET 1/5 DRIVERS CAN NOT MEET THE VISUAL REQUIREMENTS FOR THESE DIMENSIONS.

JANE DOGGET (PROFESSIONAL GRAPHICS), SAYS FEDERAL SIGNING IS BACK AROUND 1927.; ALSO THAT THE USE OF COLOR CODING COULD REDUCE THE NUMBER OF SIGNS NECESSARY AND HELP DRIVERS KEEP THEIR EYES ON THE ROAD.

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DECABOOTER, P.H., AND SINHA, K.C.
COMPARISON STUDY BY COMPUTER SIMULATION OF THE DRIVERS VISUAL PARK-TASK DURING LEFT AND RIGHT FREEWAY MERGING MANEUVERS.
HIGHWAY RESEARCH RECORD, NO. 388, 1972, PP. 1-12.

DECABOOTER AND SINHA USED COMPUTER SIMULATION TO COMPARE THE DRIVERS VISUAL TASK DURING MERGING MANEUVERS FROM RIGHT AND LEFT ENTRANCE RAMPS. THE PROPOSED MODEL PROVIDES INFORMATION ABOUT THE DISTRIBUTION OF SUCCESSFUL OBSERVATIONS (POINTS) OF A FREEWAY VEHICLE BY A RAMP DRIVER ATTEMPTING TO MERGE BEHIND THAT VEHICLE THE MODEL PERMITS ANALYSIS OF THE ON-RAMPS INDIVIDUALLY FOR VISUAL. QUALITY BY COMPARING VISUAL SUCCESSES AT SELECTED POINTS ALONG THE RAMPS.

RESULTS:

1) GUARD-RAILS, OBSTRUCTIONS, AND SHORT RAMP LENGTHS PREVENT THE DRIVER FROM SEEING FREEWAY VEHICLES UNTIL HE IS CLOSE TO THE NOSE (INTERSECTION), THE PROBABILITY THAT HE WILL NOT SEE THE VEHICLE IS INCREASED AND REACTION/DECISION

   TIME IS DECREASED.
2) THE MODEL RESULTS SHOW THAT COCKPIT INTERFERENCE IN LEFT MERGES INCREASES CLOSE TO NOSE, AND VISION IN LEFT REAR--VIEW MIRROR DURING RIGHT MERGES ARE NON-EXISTENT.
3) PROPER MERGE DILEMMA ZONES SHOULD BE UPSTREAM WITH 200-300 FT. UNOBSTRUCTED VIEW.
4) USING CONFIDENCE LEVELS BETWEEN .90-.95, THE HYPOTHESIS THAT LEFT-ON RAMPS ARE INFERIOR TO RIGHT-ON RAMPS DUE TO VISION HINDERENCES IS ACCEPTED.

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DECKER, J.D.
HIGHWAY SIGNS STUDIES - VIRGINIA.
HIGHWAY RESEARCH BOARD PROCEEDINGS, 1960, VOL. 40, PP. 593-609.

THE PURPOSE OF THIS EXPERIMENT WAS TO INVESTIGATE THE EFFECTS OF ILLUMINATION LEVEL AND COLOR COMBINATION ON SIGN MESSAGE LEGIBILITY.

THE METHOD WAS A FIELD STUDY. COLORS WERE COMPARED - GREEN ON WHITE AND WHITE MESSAGE ON BLUE BACKGROUNDS. SIZE AND SPACING WAS STANDARDIZED. THERE WERE THREE LEVELS OF ILLUMINATION - DAYLIGHT, HIGH AND LOWBEAM HEAD LIGHT SITE - RURAL HIGHWAY INTERCHANGE.

RESULTS:

1) THERE WAS NO SIGNIFICANT DIFFERENCES IN DAYLIGHT.
2) WHITE LETTERS ON BLUE BACKGROUND WERE SEEN AT SIGNIFICANTLY GREATER FOR BOTH HIGH AND LOW HIGHWAY BEAMS.

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DEWAR, R.E., AND ELLS, J.G.
COMPARISON OF THREE METHODS FOR EVALUATING TRAFFIC SIGNS.
TRANSPORTATION RESEARCH RECORD, NO. 503, 1974, PP. 38-41.

THE PURPOSE OF THE EXPERIMENT WAS TO COMPARE THREE TECHNIQUES IN EVALUATING THE SAME HIGHWAY SIGNS.

THERE WERE THREE EXPERIMENTAL METHODS:

1) FIELD EXPERIMENT ON THE HIGHWAY UNDER NORMAL DRIVING DRIVING CONDITIONS.
2) A MODIFIED ON-THE-ROAD MEASURE USING MINIATURE SIGNS ONE-THIRD OF NORMAL SIZE VIEWED AT ONE-THIRD THE SPEED OF THE FIRST EXPERIMENT.
3) LABORATORY REACTION TIME MEASURE - WAS NOT DESIGNED TO SIMULATE DRIVING SITUATIONS. USED SIGHT DISTANCE OF SIGNS AS DEPENDENT VARIABLE IN ALL THREE.

SIMILAR TRENDS WERE FOUND IN ALL THREE. PERFORMANCE WAS BETTER FOR WARNING SIGNS THAN REGULATORY SIGNS. SYMBOL SIGNS WERE IDENTIFIED EARLIER THAN LEGEND SIGNS IN TWO FIELD EXPERIMENTS BUT NOT IN THE LAB STUDY. THE SAME SUBJECTS WERE
* USED FOR BOTH OF THE FIELD STUDIES, AND DIFFERENT ONES FOR

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DEWAR, R.E., ELLS, J.G., AND MUNDY, G.
REACTION TIME AS AN INDEX OF TRAFFIC SIGN PERCEPTION.
HUMAN FACTORS, VOL. 18, NO. 4, AUG 1976, PP. 381-391.

THIS DATA WAS AN ATTEMPT TO COMPARE LABORATORY REACTION TIME MEASURES OF TRAFFIC SIGN PERCEPTION WITH PERCEPTION OF SIGNS IN AN ACTUAL DRIVING SITUATION. THE DESIRED OBJECT OF THE THREE EXPERIMENTS WAS TO DEVELOP A LAB PROCEDURE IN WHICH PERFORMANCE CORRELATES HIGHLY WITH ON-THE-ROAD PERFORMANCES, AND TO DETERMINE WHICH OF THE TWO LOADING TASKS PERFORMED SIMULTANEOUSLY WITH THE PRIMARY REACTION TIME TASK MORE CLOSELY APPROXIMATES THE REQUIREMENTS OF OPERATING A MOTOR VEHICLE.

RESULTS:

EXPER 1) A MAJOR DIFFERENCE WAS FOUND BETWEEN THE VERBAL AND SYMBOLIC MESSAGES. THE MAIN EFFECT OF MESSAGE TYPE WAS SIGNIFICANT AS WELL AS TWO-WAY INTERACTIONS WITH OTHER VARIABLES.

EXPER 2) THE ADDITION OF THE LOADING TASK ELEVATED REATION TIMES BUT DID NOT CHANGE INFLUENCE OF THE MAJOR VARIABLES OR THE TIME INTERACTIONS.

EXPER 3) THE SUPERIORITY OF THE VERBAL MESSAGES DISAPPEARS AND MESSAGE TYPE DOES NOT INTERACT WITH ANY OF THE OTHER VARIABLES. THE INCREASED DIFFICULTY IN EXTRACTING INFORMATION WAS CONSIDERED TO BE THE MAIN FACTOR IN THE LACK OF DIFFERENCE BETWEEN THE SIGNS.

GENERALLY, REACTION TIME WAS SMALLER FOR CLASSIFICATION THAN FOR IDENTIFICATION AND SMALLER FOR WARNING THAN FOR REGULATORY SIGNS; AND RESPONSES WERE FASTER FOR VERBAL THAN FOR SYMBOLIC MESSAGES.

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DODDS, T.
MINOR DISTRACTIONS CAN TRIGGER MAJOR CRASHES.
TRAFFIC SAFETY, VOL. 72, NO. 12, DEC 1972, PP. 28-29.

THIS STUDY DISCUSSES DISTRACTION SUCH AS DROPPING A CIGARETTE, SETTING A WATCH, AND SEARCHING FOR CHANGE. IT NOTES SOME EXAMPLES OF SUCH ACCIDENTS. DODDS ADDS THAT FEW DRIVERS WILL ADMIT THEY WERE DISTRACTED.

THROUGH A RUTZERS UNIVERSITY STUDY, RESULTS INDICATED DISTRACTION AS A THIRD RANKED (25%) CAUSE OF ACCIDENTS AMONG MALE STUDENTS INVOLVED IN ACCIDENTS. EVEN THOUGH DISTRACTION IS RARELHY LISTED AS THE CAUSE OF AN ACCIDENT, IT PROBABLY ACCOUNTS FOR MOST OF THE SO-CALLED MYSTERY CRASH-- THE SEEMINGLY INEXPLICABLE MISHAPS IN STRAIGHT ROADS IN GOOD WEATHER.

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DUDEK, R.A., AND COLTON, G.M.
EFFECTS OF LIGHTING AND BACKGROUND WITH COMMON SIGNAL LIGHTS ON HUMAN PERIPHERAL COLOR VISION.
HUMAN FACTORS, VOL. 12, NO. 4, AUG 1970, PP. 401-408.

THIS STUDY INVESTIGATES BINOCULAR PERIPHERAL COLOR VISION IN AN INDUSTRIAL SITUATION. THE EXPERIMENT LOOKED INTO THE POINTS AT WHICH COLOR IN A PERIPHERAL FIELD IS RECOGNIZED AND TO DETERMINE APPARENT COLOR CHANGE AS COLOR IS MOVED INWARD FROM A POSITION OUTSIDE THE SUBJECTS FIELD OF VISION PRIOR TO THE CORRECT RECOGNITION OF THE COLOR.

RESULTS:

1) INDEPENDENT VARIABLES (BACKGROUND, COLOR, ENVIRONMENTAL LIGHT LEVEL, TEST POSITION, AND COLOR OF LIGHT) HAD DIFFERENT EFFECTS ON DISTANCES AT WHICH TRUE COLOR RECOGNITION AND NO. OF ERRORS PRIOR TO RECOGNITION.
2) THE BLUE TEST LIGHT WAS THE EASIEST TO RECOGNIZE IN ALL INSTANCES WHILE WITH THE WHITE BACKGROUND, COLORS WERE RECOGNIZED AT THE LEAST DISTANCE AND MORE ERRORS WERE MADE.
3) ENVIRONMENTAL LIGHT LEVEL EFFECT INDICATED THAT A DECREMENT IN THE LIGHT LEVEL PRODUCED A PROPORTIONATE INCREASE IN THE DISTANCE AT WHICH A COLOR LIGHT WAS RECOGNIZED.

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FARBER, E., AND GALLAGHER, V.
ATTENTIONAL DEMAND AS A MEASURE OF THE INFLUENCE OF VISIBILITY CONDITIONS ON DRIVING TASK DIFFICULTY.
HIGHWAY RESEARCH RECORD, VOL. 414, 1972, PP. 1-5.

THE ARTICLE DEALS WITH THE EFFECT OF VISUAL CONDITIONS ON DRIVERS ATTENTION.

FARBER USED 6 MALE SUBJECTS HAVING THEM DRIVE THROUGH A SLALOM COURSE WHICH HAD BEEN DRIVEN THRU 5 TIMES EARLIER FOR FAMILIARITY. EACH SUBJECT WENT THE SAME SPEED, EACH WORE GOGGLES WHICH COULD BE ADJUSTED BY THE EXPERIMENTER TO 3 DIFFERENT DENSITIES, AND EACH WORE A HELMET WITH A TRANSLUCENT SHIELD WHICH COULD BE LIFTED FOR 1/2 SECOND IF THE DRIVER NEEDED IT. FARBER USED THE LIFTING OF THE SHIELD AS A MEASURE OF ATTENTIONAL DEMAND.

POOR VISUAL CONDITIONS INCREASE ATTENTIONAL DEMAND, BUT SKILLED DRIVERS WERE LESS AFFECTED.

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FLEMING, R.A.
THE PROCESSING OF CONFLICTING INFORMATION IN A SIMULATED TACTICAL DECISION-MAKING TASK.
HUMAN FACTORS, VOL. 12, NO. 4, AUG 1970, PP. 375-386.

THIS STUDY EXAMINED HUMAN CAPABILITY AT COMBINING ATTACK PROBABILITIES FROM 3 INDEPENDENT SOURCES TO ARRIVE AT AN OVERALL PROBABILITY OF ATTACK (O.P.A.).

RESULTS:

1) ERRORS WERE RECORDED WHEN SUBJECTS FAILED TO PICK HIGHEST OPA SHIP. STRATEGIES INCLUDED ADDING, INTUITIVE GUESS AND AVERAGING.
2) THE ABSENSE OF THE FEEDBACK FOR THE SECOND 100 PROBLEMS CAUSED THE FULL FEEDBACK GROUP TO GIVE POORER ESTIMATIONS WHILE THE ATTACK GROUP GAVE BETTER ESTIMATIONS.

THE EXPERIMENTERS CONCLUDED THAT THE SUBJECTS DID NOT KNOW HOW TO PROPERLY COMBINE CONFLICTING INFORMATION EVEN WHEN GIVEN FULL FEEDBACK.

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FOODY, T.J., AND TAYLOR, W.C.
AN ANALYSIS OF FLASHING SYSTEMS.
HIGHWAY RESEARCH RECORD, NO. 221, 1968, PP. 72-84.

THE INVESTIGATION EVALUATED THE EFFECTIVENESS OF VARIOUS TYPES OF FLASHING DEVICES IN REDUCING THE ACCIDENT RATE AT INTERSECTIONS ON THE RURAL STATE HIGHWAY SYSTEM. THE INVESTIGATION TRIES TO CREATE A RELATIONSHIP BETWEEN THE TYPE OF FLASHING DEVICE AND THE REDUCTION ACCIDENT. VARIABLES TO BE CONSIDERED ARE INTERSECTION GEOMETRICS, VOLUME AND LINE OF SIGHT DISTANCE.

FROM RECORDS OF ALL INTERSECTIONS IN OHIO, 200 INTERSECTIONS WHERE FLASHING DEVICE SYSTEMS WERE FIRST INSTALLED BETWEEN 1955 AND 1965 WERE CHOSEN FOR THE STUDY.

FIELD OBSERVATIONS INCLUDED:

1) DESCRIPTION OF FLASHING DEVICE.
2) INTERSECTION GEOMETRICS.
3) LINE OF SIGHT DISTANCE FROM THE MINOR ROAD ALONG THE MAIN ROAD APPROACH.

TO VERIFY THAT NO CHANGES IN FLASHING DEVICES OF INTERSECTIONS GEOMETRICS HAD TAKEN PLACE, ACCIDENT HISTORY WAS COMPILED TWO YEARS BEFORE AND TWO YEARS AFTER INSTILATION OF THE FLASHING DEVICE.

THE FLASHING DEVICE WHICH CONSISTED OF A BOUNCING BALL EITHER HORIZONTAL OR VERTICAL, RESULTS IN THE GREATEST DECREASE IN ACCIDENT RATE. NEITHER VOLUME ALONE, NOR THE RATIO OF MAIN OR MINOR ROAD VOLUMES INFLUENCED THE ACCIDENT RATE REDUCTIONS DETERMINED IN HIS HIS STUDY.

INTERSECTIONS CARRYING A HIGH VOLUME OF TRAFFIC AND CONSISTING OF A FOUR-LANE DIVIDED HIGHWAY AND A TWO-LANE ROAD DID NOT EXHIBIT A SIGNIFICANT REDUCTION IN ACCIDENTS FOLLOWING THE INSTALLATION OF A FLASHING DEVICE.

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FORBES, T.W.
A METHOD FOR ANALYSIS OF THE EFFECTIVENESS OF HIGHWAY SIGNS.
JOURNAL OF APPLIED PSYCHOLOGY, VOL. 23, 1939, PP. 669-684.

THE STUDY WAS DIVIDED UP INTO TWO PARTS:

1) LEGIBILITY - PURE- READING DISTANCE WITH UNLIMITED TIME.
   GLANCE- READING DISTANCE WITH UNLIMITED TIME.
2) ATTENTION VALUE - TARGET VALUE- CHARACTERISTICS WHICH MAKE A SIGN STAND OUT FROM OTHER SIGNS.
   PRIORITY VALUE- CHARACTERISTICS WHICH MAKE ONE SIGN READ FIRST.

DISTANCES WERE MARKED OFF IN 25 FT. UNITS. A SHUTTER WAS PLACED IN FRONT OF THE SIGN. OBSERVER WALKS FORWARD TILL LEGIBLE. THE SHUTTER WOULD TEST THE GLANCE REACTION BY OPENING FROM .2 TO .3 SECONDS. OBSERVER WALKING FORWARD AT EACH INTERVAL THAT SHUTTER OPENS (FOR GLANCE LEGIBILITY). THE SHUTTER IS LEFT OPEN FOR PURE LEGIBILITY.

RESULTS:

1) POSITION ON HIGHWAY IS AN IMPORTANT FACTOR.
2) SIGNS ARE READ TOP TO BOTTOM AND LEFT TO RIGHT FOUR OUT FIVE TIMES.
3) THREE OR FOUR WORDS IS WHAT IS MOST COMFORTABLE AND POSSIBLE AT A SINGLE GLANCE.

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FORBES, T.W.
FACTORS IN HIGHWAY SIGN VISIBILITY.
TRAFFIC ENGINEERING. VOL. 39, NO. 12, SEPT 1969, PP. 1-8 AND PP. 22-27.

THIS REPORT SUMARIZES A SYSTEMATIC STUDY OF SIGN VISIBILITY. FORBES IN 1939 OPERATED A SIMILAR GROUNDWORK STUDY. THE PURPOSE OF THE STUDY WAS TO FIND CHARACTERISTICS WHICH INCREASE SIGN EFFECTIVENESS AND TO MEASURE FACTORS AFFECTING VISIBILITY AND ATTENTION.

TWO CONTROL SITUATIONS WERE USED, ONE LAB SITUATION WHEREIN SLIDES WERE MADE USING AN ACTUAL HIGHWAY SCENE, FIRST ALONE THEN WITH A BACKGROUND ON WHICH WERE SUPERIMPOSED SIMULATION HIGHWAY SIGNS. EACH EXPERIMENT USED A DIFFERENT SERIE OF SIMULATED SIGNS. THE EFFECT SIMULATED WAS THAT OF SEEING A GROUP OF SIGNS SUDDENLY COMING FROM BEHIND A TRUCK WHICH PREVIOUSLY RESTRICTED THE VIEW.

SUBJECTS WERE REQUESTED TO SAY WHICH SIGN WAS SEEN FIRST AND BEST. A SECOND EXPERIMENT USED GREEN SIMULATED SIGNS OF FOUR DIFFERENT BRIGHTNESSES. SIGNS SEEN FIRST AND BEST WERE:

1) THOSE WITH GREATEST BRIGHTNESS CONTRAST AGAINST THE BACKGROUND.
2) THE LARGER SIGNS WHEN BRIGHTNESS WAS HELD CONSTANT.
3) RELATIVE SIZE AND CONTRAST MIGHT ENHANCE OR OPPOSE EACH OTHER.

ONE EXPERIMENT TESTED THE BACKGROUND OF ILLUMINATED ADVERTISING SIGNS (THE FOUR GREEN SIMULATED SIGNS OF DIFFERENT BRIGHTNESS SEEN AGAINST TWO BACKGROUNDS OF COMPETING SIGNS BESIDE THE ROADWAY). TWO EXPERIMENTS PRESENTED SIMULATED SIGNS AGAINST DIFFERENT COLORED BACKGROUNDS TO DETERMINE THE BEST COMBINATION FOR VISIBILITY.

MATHEMATICAL MODELS WERE COMPARED TO THE RESULTS OF THE EXPERIMENT.

OUTDOOR FULL SCALE OBSERVATIONS WERE MADE IN THE DAY AND NIGHT. CAR WAS FITTED WITH A MOVING PAPER SPEED AND DELAY RECORDER. FROM THIS EXPERIMENT, DATA WAS COLLECTED TO INDICATE MEASUREMENTS OF THE ACTUAL DISTANCE SIGNS WERE FIRST SEEN.

STUDY SHOWS IMPORTANCE OF CONTRAST BETWEEN A DARK SIGN AND A BRIGHT BACKGROUND AND VISA VERSA; AS WELL AS A CONTRAST OF THE LETTER TO THE SIGN ITSELF FOR INCREASING THE PROBABILITY THAT THE SIGN WILL BE SEEN. THE EXPERIMENT INDICATED THAT SIGNS LOCATED OVER THE HIGHWAY WERE MORE LIKELY TO BE SEEN THAN THOSE TO EITHER SIDE. THE MOST EFFECTIVE FACTORS WERE BRIGHTNESS, CONTRAST OF LETTERS TO SIGN, AND SIGN TO BACKGROUND. BRIGHTNESS RATIO AND PERCENT CONTRAST EQUATIONS MAY BE USED FOR ESTIMATION OF RELATIVE VISIBILITY OF GIVEN TYPES OF SIGN INSTILLATIONS.

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FORBES, T.W.
REVIEW OF VISIBILITY FACTORS IN ROADWAY SIGNING.
HIGHWAY RESEARCH BOARD SPECIAL REPORT, 1972, NO. 134, PP. 37-38.

IN HIS DISCUSSION, FORBES SUGGESTS THE USE OF LINES OF MARKERS RATHER THAN SMALL GROUPS OF SIGNS.

HE NOTES THAT OTHER LIGHTS AND SIGNS SURROUNDING A MARKER CAN CREATE VISUAL NOISE AND INTERFERE WITH THE DRIVERS PERCEPTION, CAUSING ERRORS.

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FORBES, T.W., SNYDER, T.E., AND PAIN, R.F.
TRAFFIC SIGN REQUIREMENTS: REVIEW OF FACTORS INVOLVED, PREVIOUS STUDIES AND NEEDED RESEARCH.
HIGHWAY RESEARCH RECORD, 1965, NO. 70, PP. 48-56.

THIS STUDY IS A REVIEW OF RESEARCH AND SUGGESTS AREAS OF FUTURE RESEARCH. THEY ANALYZE THE DRIVING TASK IN A SIMPLIFIED MAN-MADE MACHINE SYSTEMS ANALYSIS APPROACH.

THE DRIVER IS THE SENSING, DISCRIMINATING UNIT RECEIVING STIMULI FROM THE ROAD, SIGNS, AND OTHER CARS. THINGS THAT ARE PART OF THE DRIVING TASK AND OTHERS WHICH MAY DISTRACT HIS ATTENTION ARE INCLUDED IN THE STIMULI. DRIVER≠S RESPONSES TO STIMULI AFFECTS SENSORY IMPUT OF SPEED AND POSITION ON ROAD.

THEY SUGGEST FURTHER RESEARCH IS NEEDED FOR SOME LEGIBILITY FACTORS -- BRIGHTNESS, STROKE WIDTH, AND SPACING.

THE LITERATURE SHOWS THE IMPORTANCE OF ATTENTION GAINING FACTORS BUT THERE ARE TOO FEW REPORTS ON THESE FACTORS. PRACTICAL APPLICATION OF ATTENTION GAINING PRINCIPALS IS SEEN IN THE USE OF OVERSIZED STOP SIGNS.

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FORD, J.W., AND JAIN, R.
SAFETY ASPECTS OF TRAFFIC SIGNAL DESIGN.
PUBLIC WORKS, VOL. 104, NO. 9, SEPT 1973, PP. 96-101.

THIS ARTICLE OUTLINES THE STEPS TO THE DESIGN AND PLACEMENT OF A TRAFFIC CONTROL SIGNAL.

THE NEED FOR A SIGNAL HAS TO BE ESTABLISHED. THIS IS ACCOMPLISHED BY OBTAINING DATA ON THE NUMBER OF CARS ENTERING AN INTERSECTION, TURNING MOVEMENT ASSESSMENT IN THE PEAK MOMENTS, PEDESTRIAN VOLUME, PHYSICAL LAYOUT, APPROACHING SPEED OF TRAFFIC, ACCIDENTS BY TYPE, LOCATION, WEATHER DESCRIPTION, ETC.

ONCE THE NEED IS ESTABLISHED FOR THE LIGHTING, DESIGN FOR THE LAYOUT IS UNDERTAKEN. AFTER DESIGNED, THE ACTUAL LAYOUT OF THE INTERSECTIONAL HARDWARE TAKES PLACE.

SECTION 4B-12 OF THE MANUAL OF UNIFORM TRAFFIC CONTROL DEVICES (MUTCD) IS ABSTRACTED IN THIS ARTICLE. SECTION 4B-12 INCLUDES REQUIREMENTS CONCERNING ASPECTS OF VISIBILITY (APPROACHING SPEED, DISTANCE, VIEW). QUANTITY OF LIGHTS AND TYPES TO MEET MINIMUM STANDARDS.

THERE IS DISCUSSION OF DETECTOR PLACEMENT FOR SIGNAL CHANGES AND DATA ON PLACEMENT RELATED TO APPROACH SPEEDS. SPECIAL EQUIPTMENT INCLUDED: SIGNAL VISORS, LOUVERS, PROGRAMMED SIGNALS (SOLID STATE DEVICES), CONFLICT MONITORS (DISALLOWING TWO CONFLICTING LIGHTS TO FUNCTION AT ONE TIME).

IMPROPERLY DESIGNED SIGNAL INSTALATIONS OFTEN CAUSE MORE ACCIDENTS THAN THEY PREVENT.

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GORDON, D.A., AND MICHAELS, R.M.
STATIC AND DYNAMIC VISUAL FIELDS IN VEHICULAR GUIDANCE.
HIGHWAY RESEARCH RECORD, NO. 84, 1965, PP. 1-15.

THIS PAPER CONSIDERS PERCEPTUAL PROBLEMS IN VEHICULAR GUIDANCE IN THE CONTEXT OF POSTIMAL, VELOCITY AND ACCELERATION FIELDS AROUND THE MOVING VEHICLE. THE APPROACH IS TO EXAMINE THE EQUATIONS GOVERNING THESE FIELDS, AND THE FIELDS THEMSELVES, FOR FEATURES AND REGULARITIES WHICH MIGHT SERVE TO EXPLAIN HUMAN SPATIAL PERCEPTION.

RESULTS:

1) INTERPRETIVE SCALING OF VISUAL ANGLE (INVERSE OF PERSPECTIVE EFFECTS IN POSITIONAL FIELD) IS A KEY FACTOR IN SIZE, DISTANCE, AND MOTION PERCEPTION.
2) SIMPLE AND OBVIOUS FEATURES OF THE VISUAL ENVIRONMENT PROVIDE THE MOST IMPORTANT AIDS FOR VEHICULAR GUIDANCE. THE ROADWAY MAY BE USED TO OBTAIN SCALE OF TERRAIN AND OBJECTS IN IT, AND SO ON.
3) THE VELOCITY FIELD FURNISHES A REFERENCE FOR THE SEEN MOVEMENT OF OBJECTS.
4) SOME DIFFICULTIES ARE POINTED OUT IN THE MOTION-PARALLAX INDICATION OF DISTANCE.
5) ROADWAY BOUNDARIES AND LANE MARKINGS ARE USED IN ALIGNING THE MOVING VEHICLE WITH THE ROAD. THIS CONCLUSION IS BELIEVED TO CHALLENGE THE WIDELY QUOTED VIEW THAT THE FOCUS OF EXPANSION IS THE CUE FOR THE DIRECTION OF SENSED LOCOMOTION.
6) THE FORMULAS DERIVED INDICATE THAT ANGULAR ACCELERATION INCREASES AS THE SQUARE OF VEHICULAR SPEED. THE CONSEQUENCES OF THIS RELATIONSHIP FOR THE PERCEPTION OF VEHICULAR SPEED ARE INDICATED.
7) EVIDENCE IS PROVIDED THAT ANGULAR ACCELERATION IS NOT DIRECTLY SENSED SUPPOSEDLY DUE TO THE PATTERN OF THE ANGULAR ACCELERATION FIELD WHICH DOES NOT RESEMBLE ANY FAMILAR PATTERN OF VISUAL EXPERIENCE.

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HAIGHT, F.A.
A MATHEMATICAL MODEL OF DRIVER ALERTNESS.
ERGONOMICS, VOL. 15, NO. 4, JULY 1972, PP. 367-378.

THE ARTICLE DEALS WITH A TEN PARAMETER MODEL RELATING TO THE EXPERIENCE OF A DRIVER IN COMPLEX TRAFFIC.

HAIGHT DISCUSSES THE RELATIONSHIP BETWEEN THE DRIVER AND HIS CHOICE OF PARAMETER VALUES, AND THE DRIVERS OBSERVATION OF DANGER. HE DEVELOPS A MODEL TO CALCULATE THE RISK INVOLVED IN HAZARDOUS SITUATIONS. THIS PAPER IS OF THE THEORETICAL MODEL.

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HANSON, DOUGLASS, WOLTMAN, HENRY L.
SIGN BACKGROUNDS AND ANGULAR POSITION.
HIGHWAY RESEARCH RECORD, 1967, NO. 170, PP. 82-96.

THERE WERE TWO PURPOSES TO THIS STUDY:

1) TO DETERMINE ANGULAR POSITION OF SIGNS, RELATIVE TO THE DRIVER≠S VISUAL AXIS OF EXISTING SIGNS AND COMPARE DATA WITH THE LIMITS SUGGESTED BY PREVIOUS RESEARCHERS.
2) TO DETERMINE THE NATURE AND FREQUENCY OF BACKGROUNDS OF EXISTING SIGNS IN CERTAIN REPRESENTATIVE AREAS.

TO OBTAIN ANGULAR POSITION, A TRANSPARENT PLASTIC SCREEN WAS SECURED BETWEEN THE STEERING WHEEL AND WINDSHIELD. AS A SIGN WAS APPROACHED, THE DRIVER WOULD MARK ITS LOCATION ON THE SCREEN WHEN IT FIRST BECAME LEGIBLE. THE DRIVER≠S VISUAL AXIS WAS MARKED ON THE SCREEN AT A POINT OF INFINITE DISTANCE ON THE LANE AHEAD. DATA ON THE SIGN BACKGROUND WAS RECORDED AT THE SAME TIME BY AN OBSERVER IN THE CAR.

RESULTS:

1) IN FLAT TERRAIN MOST SIGNS ARE WELL WITHIN THE SUGGESTED LIMITS OF ANGULAR POSITION. IN METRO-POLITAN AND GENTLY ROLLING TERRAIN 10-37÷ OF THE SIGNS HAVE GREATER THAN OPTIMAL ANGULAR DISPLACEMENTS. IN MOUTAINOUS TERRAIN, 53÷ OF THE SHOULDER MOUNTED SIGNS FALL OUTSIDE THE RANGE.
2) DARK TREES WERE THE BACKGROUND OF SIGNS 23÷ OF THE TIME. SKY AND BRIDGES WERE THE NEXT MOST FREQUENT. THE PERCENTAGE OF BACKROUND WAS BROKEN INTO SIX TYPES OF AREAS. I.E. METROPOLITAN, FLAT, HILLY, DESERT ETC; INTO TYPES OF FACILITY I.E. OVERHEAD, AT GRADE, DEPRESSED; INTO ROADWAY ENVIRONMENT I.E. RURAL, SUBURBAN, BUSINESS.

THE ROUTE INCLUDED 1560 MILES OF FREEWAYS IN NEVADA, WISCONSIN, MINNISOTA, ILLINOIS, N.Y., PENN., AND CALIFORNIA, WITH 4054 DESTINATION AND DISTANCE SIGNS. ALL DATA WAS TAKEN IN THE SUMMER TO ELIMINATE SEASONAL VARIATION. ALL TESTS WERE DONE IN THE DAYTIME.

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HARTE, D.B.
ESTIMATES OF THE LENGTH OF HIGHWAY GUIDELINES AND SPACES.
HUMAN FACTORS, VOL. 17, NO. 5, OCT 1975, PP. 455-460.

THE RESEARCHER IS INTERESTED IN THE ACCURACY WITH WHICH THE LENGTHS OF LINES AND SPACES ON STATE HIGHWAYS ARE ESTIMATED FROM MEMORY AND UNDER ACTUAL DRIVING CONDITIONS. HE ALSO ADDRESSES THE IMPACT ON DRIVING SKILLS AND PERFORMANCE.

EXPER 1) SUBJECTS FIRST MADE A VARIETY OF ESTIMATES FROM MEMORY OF THE LENGTHS OF SEGMENTS OF GUIDELINES ON MASS. STATE HIGHWAYS AND THE LENGTH OF SPACE BETWEEN SEGMENTS. THEN SUBJECTS WERE DRIVEN AROUND ON LINED HIGHWAYS AND ROADS WHILE BEING GIVEN VARIOUS ESTIMATION TASKS.

RESULTS:

1) IN MOST TASK THE MAJORITY OF THE SUBJECTS UNDERESTIMATED THE TASK LENGTHS.
2) ESTIMATIONS FROM MEMORY CORRELATED HIGHLY WITH WHAT IS ACTUALLY SEEN AT HIGH SPEEDS.
3) MALES ESTIMATED WITH GREATER ACCURACY AT ALL VELOCITIES WHILE FEMALES HAD TO GO 20 MPH. TO REACH THE ACCURACY MALES HAD AT 60 MPH.
4) LINE-SPACE AND VELOCITY WERE HIGHLY SIGNIFICANT VARIABLES AFFECTING THE ESTIMATES ON THE ROAD.

EXPER 2) HALF OF THE SUBJECTS LIVED ON ROADS WITH GUIDELINES AND HALF DID NOT. SUBJECTS WERE RANDOMLY CALLED ON THE PHONE AT NIGHT AND ASKED TO ESTIMATE FROM MEMORY THE LENGTH OF ONE SEGMENT OF THE GUIDELINES AND THE LENGTH OF SPACE BETWEEN SEGMENTS.

RESULTS:

1) SUBJECTS WHO RESIDED ON ROADS WITH GUIDELINES WERE SOMEWHAT BETTER AT ESTIMATING LENGTHS THAN THE OTHERS.
2) MALES ESTIMATED WITH GREATER ACCURACY.
3) THE LENGTHS WERE UNDERESTIMATED THE MOST OF THE TIME.

THE RESEARCHERS SUGGEST THAT DRIVING TESTS BE MODIFIED TO TEST FOR DEPTH PERCEPTION ALSO SINCE DYNAMIC VISUAL ACUITY IS APPARENTLY NOT ENOUGH.

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HEAD, J.A.
PREDICTING TRAFFIC ACCIDENTS FROM ELEMENTS ON URBAN EXTENSIONS OF STATE HIGHWAYS.
HIGHWAY RESEARCH BOARD BULLETIN, 1959, NO. 208, PP. 45-63.

THIS STUDY EXAMINED ROADSIDE ELEMENTS: COMMERCIAL AND RESIDENTIAL UNITS, DRIVEWAYS, INTERSECTIONS, SIGNALS AND POSTED SPEED.

THIS WAS A CORRELATIONAL STUDY BASED ON ACCIDENT AND AVERAGE DAILY TRAFFIC (ADT) DATA FROM 1954-55. HEAD ANALYZED 426 SECTIONS OF OREGON HIGHWAYS. HE DEVELOPED REGRESSION EQUATIONS FOR PREDICTING ACCIDENT FREQUENCIES.

RESULTS:

1) THERE WAS A DEFINITE RELATIONSHIP BETWEEN CERTAIN ELEMENTS AND ACCIDENT RATES, AND THE PREDICTABILITY INCREASES WITH THE ADT.
2) ON LOW VOLUME ROADS THERE IS NO RELATIONSHIP BETWEEN ROADSIDE ELEMENTS AND ACCIDENT RATE.
3) ACCIDENT RATES INCREASE WITH INCREASES IN COMMERCIAL UNITS (BUILDINGS), SIGNALS, INTERSECTIONS, PAVEMENT WIDTH, AND ADT. ACCIDENT RATES INCREASE WHEN POSTED SPEED DECREASES.

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HEATHINGTON, K.W., WORRALL, R.D., AND HOFF, G.C.
AN ANALYSIS OF DRIVER PREFERENCES FOR ALTERNATIVE VISUAL INFORMATION DISPLAYS.
HIGHWAY RESEARCH RECORD, 1970, NO. 303, PP. 12-16.

THIS STUDY ATTEMPTED TO EVALUATE WHAT TYPES OF INFORMATION PERTAINING TO CONGESTION AHEAD DRIVER≠S PREFERRED.

THE METHODOLOGY WAS A QUESTIONAIRE PAIRED COMPARISON.

RESULTS:

1) TRAFFIC INFORMATION WAS PREFERRED TO NO INFORMATION.
2) FOR HEAVY CONGESTION, DRIVER≠S PREFERRED AN ACCIDENT--DESCRIPTION TO A SPEED DESCRIPTION: EX. ACCIDENT AHEAD - HEAVY CONGESTION NEXT 3 MIN. WAS PREFERRED TO SPEED 5-15 MPH NEXT 3 MIN.
3) DELAY AND OR TRAVEL TIME WERE NOT DEEMED VERY USEFUL BY DRIVERS.

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IVEY, D.L., LEHTIPUV, E.K., AND BUTTON, J.W.
RAINFALL AND VISIBILITY - THE VIEW BEHIND THE WHEEL.
JOURNAL OF SAFETY RESEARCH, VOL. 7, NO. 4, DEC 1975, PP. 9-17.

THIS ARTICLE DEALS WITH VISIBILITY OBSERVATIONS AND THE INFLUENCE OF REDUCED VISIBILITY ON THE OPERATION OF MOTOR VEHICLES.

DATA WAS COLLECTED FROM VARIOUS LITERATURE SHOWING THE LOW PROBABILITY OF DRIVING IN HEAVY RAINFALL, AND THE THEORY OF VISIBILITY AS INFLUENCED BY RAINFALL. AN EXPERIMENT USING FOUR DIFFERENT TARGETS IN RAINFALL CONFIRMED THIS THEORY.

RESULTS:

RAINFALL OCCURS VERY INFREQUENTLY AND SHOULD NOT HAVE A MAJOR EFFECT ON HIGHWAY DESIGN. AUTHOR RECOMMENDED THAT DRIVERS USE LOW BEAM HEADLIGHTS WHEN DRIVING IN A DAYTIME RAINFALL TO INCREASE VISIBILITY.

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JOHANNSON, G. AND BACKLUND, F.
DRIVERS AND ROAD SIGNS.
ERGONOMICS, 1970, VOL. 13, NO. 6, PP. 749-759.

THIS WAS A STUDY OF HOW EFFECTIVE ROAD SIGNS ARE IN COMMUNICATING WITH DRIVERS.

DRIVERS WERE STOPPED SHORTLY AFTER HAVING PASSED DIFFERENT SIGNS AND WERE QUIZZED ABOUT THE SIGNS.

RESULTS:

1) NO SIGNS COMMUNICATE WITH 100% OF THE DRIVERS.
2) THE AUTHORS CONCLUDED THAT THE ROADSIGN SYSTEM (IN SWEEDEN) TO A HIGH DEGREE DOES NOT ACHIEVE ITS PURPOSE.

THE AUTHORS MAY BE UNWARRANTED IN THEIR CONCLUSION IN THAT THERE WAS OVER A MINUTE BETWEEN PASSING A SIGN AND THE DATA COLLECTION. IT IS POSSIBLE THAT THE DRIVER≠S COULD HAVE FORGOTTEN THE INFORMATION. ALSO, THE TRAINING OF BEING STOPPED AND QUESTIONED BY POLICE COULD ALSO MAKE ONE FORGET.

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KAO, H.S.R., NAGAMACHI, M.
VISUAL-MANUAL FEEDBACK MECHANSIM IN HUMAN VEHICULAR PERFORMANCE.
ERGONOMICS, 1969, VOL. 12, NO. 5, PP. 741-751.

THIS PAPER DESCRIBES A CYBERNETIC APPROACH TO ANALYZING DRIVER BEHAVIOR. THE CYBERNETIC CONCEPT IS DEFINED AS A DYNAMIC CLOSED-LOOPED FEEDBACK-REGULATED DRIVER-VEHICLE-ROAD TRACKING SYSTEM. THE THREE LEVELS OF SENSORY FEEDBACK USED WERE: REACTIVE, INSTRUMENTAL, AND OPERATIONAL.

THE MAIN CONCERN OF THE THREE EXPERIMENTS WAS THE DYNAMIC OPERATIONAL FEEDBACK THAT WAS NECESSARY IN THE RELATION OF THE THE VEHICLE TO THE ROAD. SPECIFIC OPERATIONAL FEEDBACK FACTORS THAT WERE APPLIED TO THIS CYBERNETIC MODEL ARE: SPATIAL DIFFERENCE BETWEEN THE ROADWAY COURSE AND THE CHANGES IN POSITION AND DIRECTION OF THE VEHICLE IN MOTION. CLEAR VISION OF THE FRONT AND REAR ENDS OF THE AUTOMOBILE WAS HYPOTHESIZED TO BE THE CRITICAL FACTOR IN CONTROL AND GUIDANCE OF THE VEHICLE. THREE EXPERIMENTS ON BACKING, PARALLEL PARKING AND FORWARD DRIVING WERE RUN ON A TEST TRACK WITH BOTH CLEAR AND OBSTRUCTED VISION OF THE OPERATIONAL FEEDBACK. TAPE WAS USED TO DESTRUCT VISION. OBVIOUSLY, THE RESULTS CONFIRMED THE THEORETICAL ASSUMPTIONS. THE IMPLICATIONS FOR THE CONCEPTS OF FEEDBACK ON DRIVER BEHAVIOR ARE DISCUSSED AND EVALUATIONS OF CERTAIN MODEL AUTO WINDOWS ARE PRESENTED.

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KING, G.F.
SOME EFFECTS OF LATERAL SIGN DISPLACEMENT.
HIGHWAY RESEARCH RECORD, 1970, NO. 325, PP. 15-29.

THIS WAS A STUDY OF THE EFFECTS OF DISPLACING SIGNS AT DIFFERENT DISTANCES TO THE SIDE OF THE ROAD.

THE METHODOLOGY WAS A MATHEMATICAL AND GEOMETRIC ANALYSIS OF PLACING SIGNS VARYING THE DISTANCES.

A DRIVER HAD FROM THE TIME THE SIGN BECAME LEGIBLE (F(LETTER SIZE)) TILL IT WAS OUTSIDE HIS FIELD OF VISION (F(MAX. DIVERGENCE)) TO READ A SIGN.

KING POINTED OUT THAT AN ANGLE OF 10 DEGREES IS GIVEN AS THE ACCEPTABLE MAX. DIVERGENCES.

THE MAIN POINT IS THAT THE REMOVAL OF SIGNS IMMEDIATELY ADJACENT TO THE HIGHWAY MARKEDLY REDUCES READING TIME.

SIGNS ON CURVES AND OVERHEAD WERE ALSO DISCUSSED.

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KING, G.F., AND GOLDBLATT, R.B.
RELATIONSHIP OF ACCIDENT PATTERNS TO TYPE OF INTERSECTION CONTROL.
TRANSPORTATION RESEARCH RECORD, 1975, NO. 540, PP. 1-12.

THIS STUDY INVESTIGATED CHANGE IN ACCIDENT PATTERNS ACCOMPANYING CHANGE IN INTERSECTION CONTROL.

THE INVESTIGATION INCLUDED A REVIEW OF PREVIOUSLY MADE STUDIES, ON ANALYSIS OF BEFORE AND AFTER ACCIDENT DATA, AND A DETAILED STATISTICAL ANALYSIS OF A LARGE, SPECIALLY ASSEMBLED, NATIONWIDE ACCIDENT DATA BASE.

ANALYSIS OF VARIANCE AND REGRESSION TECHNIQUES WERE USED TO SHOW THAT THE RELATIONSHIP OF ACCIDENT PATTERNS TO TYPE OF CONTROL MUST BE REPRESENTED BY A COMPLEX MODEL AND THAT A SIMPLE SIGNAL -- NO SIGNAL DIVISION CANNOT EXPLAIN CHANGES IN ACCIDENT PATTERNS.

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KONZ, S., AND MCDOUGAL, D.
THE EFFECT OF BACKGROUND MUSIC ON THE CONTROL ACTIVITY OF AN AUTOMOBILE DRIVER.
HUMAN FACTORS, VOL. 10, NO. 3, 1968, PP. 233-244.

THE ARTICLE DEALS WITH THE EFFECTS OF SILENCE, SLOW MUSIC, AND TIJUANA BRASS MUSIC ON THE CONTROL ACTIVITY OF DRIVERS.

KONZ AND MCDOUGAL USE 24 MALES AS SUBJECTS. EACH DROVE THE TEST CIRCUIT IN 3 CONDITIONS: NO MUSIC, SLOW MUSIC, AND TIJUANA BRASS MUSIC. A GREESHIELD DRIVEOMETER (1965) WAS UTILIZED TO MEASURE VARIOUS ASPECTS OF THE SUBJECTS DRIVING BEHAVIOR. THEY FOUND THAT LOW DRIVING ACTIVITY OCCURED IN NO MUSIC AND TO SOME EXTENT IN SLOW MUSIC, AND HIGH DRIVING ACTIVITY TIJUANA BRASS MUSIC. BROWN (1965) DID A SIMILAR EXPERIMENT.

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LADAN, C.J., HERON, R.M., AND NELSON, T.M.
A SIGNAL-DETECTION EVALUATION OF FLAT VS. CURVED MARKER PERFORMANCE.
PERCEPTUAL AND MOTOR SKILLS, 1974, VOL. 39, PP. 355-358.

DRIVING DECISIONS BASED ON TRAFFIC MARKERS PLACED AT ACUTE-ANGLED INTERSECTIONS ARE CONSIDERED WITHIN THE FRAMEWORK OF THE THEORY OF SIGNAL DETECTABILITY. THE IMPLIED TASK REQUIRES A BINARY DECISION BASED ON SENSORY INFORMATION HAVING SOME UNCERTAINTY AND THUS IS AMENABLE TO ANALYSIS WITHIN THIS FRAMEWORK. THE ABILITY TO SEPARATE THE PSYCHOLOGICAL AND SENSORY COMPONENTS OF PERFORMANCE CAN EXTEND ANALYSES FROM PREVIOUS RESEARCH WITH CURVED AND FLAT MARKERS. DATA FROM PRIOR LABORATORY STUDIES RENDERED D≠ VALUES OF 1.08 AND 2.25 FOR THE FLAT AND CURVED TARGETS RESPECTIVELY, THUS LENDING STRONG SUPPORT TO THE HYPOTHESIS THAT SLANT IS MORE ACCURATELY DISCRIMINATED WHEN A CURVED MARKER IS VIEWED.

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LADAN, C.J., AND NELSON, T.M.
EFFECTS OF MARKER TYPE, VIEWING ANGLE, AND VEHICLE VELOCITY ON PERCEPTION OF TRAFFIC MARKERS IN A DYNAMIC VIEWING SITUATION.
HUMAN FACTORS, 1973, VOL. 15, PP. 9-16.

THE EFFECTS OF TWO TYPES OF STOP MARKERS, NINE ANGLES OF ORIENTATION, FOUR VEHICLE VELOCITIES, AND THEIR INTERACTIONS WERE STUDIED IN A DYNAMIC TRAFFIC SITUATION. BECAUSE STOP MARKERS ARE SEEN IN CONSTANT TRANSFORMATION IN ACTUAL DRIVING SITUATIONS, THE EXPERIMENT STUDIED DYNAMIC CONDITIONS IN THE LABORATORY BY VARIATION OF THE MENTIONED FACTORS IN SHORT (10 SEC) FILM CLIPS. THIRTY SUBJECTS RESPONDED TO EACH CLIP IN ONE OF THREE POSSIBLE CATEGORIES: 1) STOP, 2) NOT STOP, 3) NOT SEEN (NOT DETECTED). RESPONSES OF THE FIRST TWO TYPES WERE THEN CATEGORIZED AS EITHER CORRECT OR IN ERROR, BASED ON STIMULUS ORIENTATION.

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LIVNER, M., PRASHKER, J., AND UZAN, J.
VISIBILITY PROBLEMS IN CREST VERTICAL CURVES.
HIGHWAY RESEARCH RECORD, NO. 312, 1970, PP. 76-84.

THE ARTICLE DEALS WITH VISIBILITY PROBLEMS IN CREST VERTICAL CURVES FOR OVER TAKING VEHICLES INSIDE THE CURVE, ONCOMING VEHICLES OUTSIDE THE CURVE, AND BOTH VEHICLES OUTSIDE THE CURVE.

LIVNER, PRASHKER, AND UZAN RAN AN ANALYSIS OF THESE CONDITIONS USING A COMPUTER SOLVED EQUATION FOR CURVES WITH SLOPE DIFFERENCE RANGING FROM 2-12↓. RESULTS WERE IN GRAPH FORM DETERMINING THE LENGTH OF THE NO-OVERTAKING ZONE FOR A TWO-LANE TWO-WAY HIGHWAY.

IN ORDER TO REDUCE THE NO-OVERTAKING ZONE, IT SHOULD PREFERABLY BE AS SHORT AS POSSIBLE WITHIN REQUIRED LIMITS OF OVERTAKING VISIBILITY AND DRIVING CONVENIENCE.

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LUCE, T.S.
VIGILANCE AS A FUNCTION OF STIMULUS VARIETY AND RESPONSE COMPLEXITY.
HUMAN FACTORS, VOL. 6, FEB 1964, PP. 101-110.

THE ARTICLE DEALS WITH THE EFFECTS OF STIMULUS VARIETY AND RESPONSE COMPLEXITY ON VIGILANCE.

LUCE USES UNDERGRADUATES AND GRADUATE STUDENTS, SEVEN MALES AND 3 FEMALES AS SUBJECTS. SUBJECTS RESPONDED TO VISUAL SIGNALS PRESENTED, BY PRESSING THE APPROPRIATE BUTTON FOR EACH SIGNAL. ARTIFICIAL SIGNALS WEE USED TO INCREASE THE VARIETY BUT SUBJECTS WERE NOT TO RESPOND TO THE AS. THE TASK WAS ALSO MADE MORE COMPLEX IN ONE CONDITION, BY HAVING THE SUBJECTS REMEMBER THE PREVIOUS SIGNAL. SUBJECTS REACTION TIMES AND ACCURACY WERE MEASURES OF VIGILANCE.

HE FOUND THAT STIMULUS VARIETY AND RESPONSE COMPLEXITY INCREASED VIGILANCE PERFORMANCE.

THE DISCUSSION GIVES IMPLICATIONS OF EXPERIMENTS FOR APPLIED USE, SUCH AS AVOIDING UNCHANGING STIMULI, INTRODUCING EXTRANEOUS STIMULI INTO A TASK WHICH INVOLVES LONG PERIODS OF NON-STIMULATION AND CHANGE TASK REQUIREMENTS FOR LONG TASKS.

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MICHAUT, G.
THE EFFECTS OF DISTRACTION ON AUTOMOBILE DRIVING.
ERGONOMICS, 1967, VOL. 10, NO. 6, P. 721.

THIS WAS A STUDY OF THE EFFECTS OF A DISTRACTING TASK ON DRIVING BEHAVIOR.

SUBJECTS WERE DRIVING ON A TEST TRACK AND WERE GIVEN A BINARY-CHOICE TASK TO PERFORM WHILE DRIVING.

RESULTS:

1) THE HANDLING OF A VEHICLE IS VERY AUTOMATED FOR DRIVERS DRIVEN MORE THAN 30,000 KMS.
2) SPEED AND PRECISION OF DRIVING SEEMED TO BE AFFECTED DIFFERENTLY BY A DISTRACTION STRESS.
3) THERE IS NO TRANSFER OF LEARNING FROM A SITUATION WITH DISTRACTION STRESS TO A SITUATION WITHOUT.

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MOORE, W.L. JR., AND HUMPHREYS, J.B.
SIGHT DISTANCE OBSTRUCTIONS ON PRIVATE PROPERTY AT URBAN INTERSECTIONS.
TRANSPORTATION RESEARCH RECORD, NO. 541, 1975, PP. 31-39.

THE ARTICLE DEALS WITH CURRENT PROCEDURES USED TO CORRECT SIGHT DISTANCE OBSTRUCTIONS ON PRIVATE PROPERTY AT URBAN INTERSECTIONS.

MOORE AND HUMPHREYS SENT QUESTIONAIRES TO STATE, COUNTY, AND MUNICIPAL TRAFFIC ENGINEERS THROUGHOUT THE U.S. TO FIND OUT THE PROCEDURE FOR REMOVAL OF OBSTRUCTIONS ON PRIVATE PROPERTY; LAWS, ORDINANCES, ETC...

BASED ON THE RESPONSES RECOMENDATIONS WERE MADE FOR CHANGING LAWS, ORDINANCES, AND OTHER METHODS FOR REMOVAL OF OBSTRUCTIONS.

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MOURANT, R.R., AND ROCKWELL, T.H.
MAPPING EYE MOVEMENT PATTERNS TO THE VISUAL SCENE OF DRIVING.
HUMAN FACTORS, VOL. 12, NO. 1, FEB 1970, PP. 81-87.

THE ARTICLE DEALS WITH THE EFFECTS OF EYE MOVEMENT PATTERNS ON DRIVING.

MOURANT AND ROCKWELL USE 8 MALE COLLEGE STUDENTS AGES 21-31 FOR DRIVING SUBJECTS. THE EYE MOVEMENT PATTERNS FOR EACH SUBJECT IN 3 TRIAL DRIVES ON A HIGHWAY, WERE RECORDED AND COMPARED. THE FIRST TRIAL WAS FOR THE SUBJECT TO BECOME FAMILIAR WITH THE ROAD, THE SECOND THE SUBJECT WAS TO USE WHAT WAS NECESSARY AS FAR AS VISUAL SIGNS IN ORDER TO COMPLETE THE TRIAL, AND LASTLY, THE SUBJECT WAS TO COMPLETE THE TRIAL WITHOUT USING SIGNS. THE TWO INDEPENDENT VARIABLES WERE ROUTE FAMILIARITY AND DRIVING CONDITIONS.

DURING TRIAL 1, THE SUBJECTS SAMPLED A WIDE AREA IN FRONT OF THEM, BUT BY TRIAL 3, SAMPLING WAS CONFINED TO A SMALLER AREA. ROUTE FAMILIARITY PLAYS AN IMPORTANT ROLE IN VISUAL SAMPLING STRATEGIES.

DISCUSSION CONCLUDES THAT PERIPHERAL VISION IS USED TO MONITOR MANY DRIVING CUES, IT IS IMPORTANT TO HAVE CLEARLY VISIBLE MARKERS ON OUR ROADS.

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MOURANT, R.R., AND ROCKWELL, T.H.
STRATEGIES OF VISUAL SEARCH BY NOVICE AND EXPERIENCED DRIVERS.
HUMAN FACTORS, VOL. 14, NO. 4, AUG 1972, PP. 325-335.

THE ARTICLE DEALS WITH THE VISUAL PROCESSES OF NOVICE DRIVERS AS COMPARED TO EXPERIENCED DRIVERS.

MOURANT AND ROCKWELL USED 6, 16-17 YR. MALES AS NOVICE SUBJECTS AND 4 EXPERIENCED DRIVERS WITH OVER 8,000 MILES OF DRIVING PER YEAR OVER THE PAST FIVE YEARS. ALL SUBJECTS DROVE A TEST CIRCUIT WITH THE VISUAL MOVEMENTS MEASURED. NOVICE DRIVERS RECEIVED TRAINING ON THREE LEVELS IN ADDITION TO THE INITIAL TEST RUN, IN ORDER TO TEST THE IMPROVEMENT DUE TO EDUCATION.

THEY FOUND THAT NOVICE DRIVERS PERFORMED FAR BELOW EXPERIENCED DRIVERS IN THER VISUAL QUICKNESS AND ACCURACY, BUT IMPROVED AFTER TRAINING.

THE DISCUSSION SUGGESTS THE NEED FOR NOVICE DRIVERS TO DEVELOP SKILL IN ACQUIRING VISUAL INFO, BEFORE BEING ALLOWED TO DRIVE ON PUBLIC ROADS.

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NELSON, T.M., AND LADAN, CAROL J.
SURFACE COLOURATION, LETTERING AND REFERENTIAL DIMENSION OF TRAFFIC MARKER PERCEPTION.
PERCEPTUAL AND MOTOR SKILLS, 1972, VOL. 35, PP. 867-873.

FIVE EXPERIMENTAL TRAFFIC MARKERS DIFFERENTIATED WITH RESPECT TO COLOURATION AND LETTERING WERE EACH PRESENTED AT 7 ANGLES OF ORIENTATION RANDOMLY REPEATED 5 TIMES. FIVE GROUPS COMPRISING 15 DRIVERS PER GROUP GAVE JUDGEMENTS OF SHAPE AND SLANT. IT WAS FOUND THAT SIGNALLING ASPECTS OF THE MARKER (FORM, COLOURATION AND LETTERING) PRODUCED SIGNIFICANT DIFFERENCES UPON APPARENT SHAPE. DIFFERENCES IN SLANT PERCEPTION WERE NOT DEPENDENT UPON THE THREE SIGNALLING CHARACTERISTICS. CONSISTENT WITH PRIOR RESEARCH, THE REFERENCE ASPECT OF THE MARKER (ANGLE OF ORIENTATION) PRODUCED LARGE ERRORS OF UNDERESTIMATION PARTICULARLY AT THE MOST ACUTE ANGLES. THE PERCEPTUAL FUNCTIONS SUGGEST THAT SYSTEMATIC DIFFERENCES SEPARATE PHYSICAN AND PSYCHOLOGICAL SPACES.

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NORTH CAROLINA UNIVERSITY
BILLBOARDS AND HIGHWAY ACCIDENTS.
HIGHWAY SAFETY HIGHLIGHTS, VOL. 8, NO. 6, OCT 1974, P. 1.

THIS WAS A STUDY USING A COMPUTER SEARCH OF LITERATURE WHICH PRODUCED NOTHING WHICH COULD CLEARLY INDICATE THAT BILLBOARDS CAUSED ACCIDENTS.

IT WAS SUGGESTED THAT MORE IN DEPTH RESEARCH IS NEEDED.

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OLSEN, RICHARD
REVIEW OF VISIBILITY FACTORS IN ROADWAY SIGNING.
HIGHWAY RESEARCH BOARD SPECIAL REPORT, 1972, NO. 134, PP. 39-40.

THIS STUDY SUGGESTS THE USE OF AN ARTIFICIAL SURROUND, SUCH AS A FLAT BLACK METAL SCREENING TO PROVIDE A BREAK IN THE CLUTTERED ENVIRONMENT AND INCREASING THE TARGET VALUE OF A SIGN. OLSEN WARNS THAT IT WOULD REDUCE STANDARDIZATION AND INCREASE COST AND MOUNTING REQUIREMENTS BECAUSE OF ADDITIONAL WIND RESISTANCE.

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PLUMMER, R.W., AND KING, L.E.
A LABORATORY INVESTIGATION OF SIGNAL INDICATIONS FOR PROTECTED LEFT TURN.
HUMAN FACTORS, VOL. 16, NO. 1, FEB 1974, PP. 37-45.

THIS STUDY INVESTIGATED AND COMPARED DRIVER COMPREHENSION AND UNDERSTANDING OF DIFFERENT TYPES OF LEFT-TURN SIGNAL CLEARANCE INDICATIONS FOR PROTECTED LEFT TURNS.

40 MALE AND FEMALE SUBJECTS WERE PRESENTED WITH COLOR SLIDES AND COLOR MOTION PICTURE FILM SEGMENTS OF 19 LEFT--TURN SIGNAL INDICATIONS IN 14 DIFFERENT SEQUENCES. THE SEQUENCES WERE DIVIDED INTO 3 GROUPS OF RESPONSES (YES, PERHAPS, NO). EACH SUBJECT WAS PRESENTED WITH EACH OF THE 14 SEQUENCES AND ASKED TO ANSWER THE QUESTION WOULD YOU MAKE A LEFT TURN≥ GIVEN A CERTAIN SEQUENCE. THE SUBJECT INDICATED HIS ANSWER BY PRESSING ONE OF 3 BUZZERS MARKED YES, PERHAPS, AND NO. THE ACCURACY AND REACTION TIMES WERE RECORDED WHICH ALSO WERE THE DEPENDENT VARIABLES. THE SUBJECTS AND THE SIGNAL INDICATIONS WERE THE INDEPENDENT VARIABLES.

THE EXPERIMENT HAD TWO PARTS. PART ONE TESTED SUBJECTS RESPONSES TO RANDOM INDIVIDUAL SIGNAL INDICATIONS. PART TWO REVIEWED AN ENTIRE SIGNAL INDICATION SEQUENCE CONTAINING 4-5 SIGNAL INDICATIONS. THE LATTER WAS CONSIDERED THE LEAST DIFFICULT OF THE TWO BECAUSE IT SIMULATED AN ACTUAL DRIVING SEQUENCE.

RESULTS:

1) NONE OF THE FLASHING SIGNALS WERE EFFECTIVE (AS COMPREHENSABLE TO THE SUBJECT AS THE NON-FLASHING).
2) THE PERHAPS GROUP OF SIGNALS CAUSED THE GREATEST AMOUNT OF UNCERTAINTY IN THE SUBJECTS. THE EXPERIMENTER CONCLUDES THAT THE PERHAPS CONFIGURATION WAS A DIFFICULT CONCEPT FOR SUBJECTS TO GRASP.
3) A COMPARISON OF PART I AND II YIELDED CONSISTENT RESULTS.

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PLUMMER, R.W., AND KING, L.E.
MEANING AND APPLICATION OF COLOR AND ARROW INDICATIONS FOR TRAFFIC SIGNALS.
HIGHWAY RESEARCH BOARD, 1973, NO. 445, PP. 34-44.

THIS IS MORE SIMILAR TO A STUDY THAN AN EXPERIMENT. THE ARTICLE DEALS WITH THE EFFECTIVENESS IN CONVEYING THEIR INTENDED MESSAGE TO THE DRIVER. 19 SIGNAL INDICATIONS WERE TESTED USING COLLOR SLIDES AND COLOR MOVIES. COLLECTIONS OF ACCURACY AND REACTION TIME WERE ANALYZED BY ANALYSIS OF VARIENCE. FOUR OF THE INDICATIONS WERE SUPERIOR AND WERE TESTED UNDER FIELD CONDITIONS. BY THE USE OF THE LAB STUDY, THE NO. POF SIGNAL SEQUENCES TO BE FIEED TESTED WAS REDUCED FROM 14-3.

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REILLY, W.R., AND WOODS, D.L.
THE DRIVER AND TRAFFIC CONTROL DEVICES.
TRAFFIC ENGINEERING, JUNE 1967, VOL. 37, NO. 9, PP. 49-52.

THIS WAS A STUDY OF DRIVER COMPREHENSION OF TRAFFIC SIGNS AND SIGNALS. THE METHODOLOGY WAS A QUESTIONAIRE.

THEY FOUND THAT THE MAJORITY OF DRIVERS DO NOT UNDERSTAND MANY SIGNS AND SIGNALS, ESPECIALLY THE YIELD SIGN.

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REISS, M.L., AND LUNENFELD, H.
FIELD OF VIEW DIRECTLY BEHIND LARGE TRUCKS AND BUSES.
TRANSPORTATION RESEARCH RECORD, NO. 562, 1976, PP. 93-105.

THE ARTICLE DEALS WITH THE REAR VIEW INFORMATION A DRIVER NEEDS TO REDUCE ACCIDENT RISK IN VARIOUS DRIVING SITUATIONS.

REISS AND LUNENFELD SPECIFICALLY DEALT WITH THE AREA DIRECTLY BEHIND SMALL TRUCKS, LARGE TRUCKS, AND BUSES. ACCIDENT DATA WAS COLLECTED BY RIDING WITH DRIVERS AND RECORDING RISK AND INFORMATION NEEDS.

THEY FOUND THAT DRIVING RISK INCREASED WHEN BACKING, TURNING, SLOWING AND STOPPING IN THAT ORDER.

THE MOST PROMISING REAR VISION SYSTEMS TO DECREASE RISK ARE: TELEVISION SYSTEMS, DUPPLER RADAR, AND PROXIMITY SENSORS. TOOK INTO ACCOUNT ENVIRONMENT, COST, MAINTAINABILITY, AND AVAILABILITY.

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REYNOLDS, R.E.
DETECTION AND RECOGNITION OF COLORED SIGNAL LIGHTS.
HUMAN FACTORS, VOL. 14, NO. 3, JUNE 1972, PP. 227-236.

THE EXPERIMENTERS WERE TRYING TO DETERMINE THE EFFECTIVE COLORS FOR STIMULUS LIGHTS AS MEASURED BY SPEED OF DETECTION AND ACCURACY OF IDENTIFICATION. INTERACTIONS BETWEEN STIMULUS COLOR, BACKGROUND COLOR AND AMOUNT OF AMBIENT ILLUMINATION WERE ALSO CONSIDERED. TWO EXPERIMENTS WERE RUN.

RESULTS:

1) EXPERIMENTS I AND II INDICATE THE RED SIGNAL LIGHT ATTRACTS THE GREATEST AMOUNT OF ATTENTION FOLLOWED BY A GREEN, YELLOW, AND LASTLY WHITE LIGHT.
2) THE RELATIONSHIP BETWEEN RESPONSE TIMES AND STIMULUS COLORS WAS ATTRIBUTABLE TO COLOR DIFFERENCES NOT BRIGHTNESS DIFFERENCES.
3) A HIGH LEVEL OF AMBIENT ILLUMINATION INCREASED THE ABSOLUTE REACTION TIME TO ALL STIMULUS COLORS BY LOWERING BRIGHTNESS CONTRAST BETWEEN TARGET AND BACKGROUND.
4) REACTION TIME INCREASED FOR DETECTION AND IDENTIFICATION CONDITION IN EXPERIMENT II RELATIVE TO DETECTION ONLY CONDITION.

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ROBERTSON, H.D.
URBAN INTERSECTIONS: PROBLEMS IN SHARING SPACE,
TRAFFIC ENGINEERING, 1976, VOL. 46, NO. 2, PP. 22-25.

THIS ARTICLE DISCUSSES CONSIDERATIONS AND PROVISIONS FOR PEDESTRIANS TO INCREASE SAFETY. THE FIRST PHASE OF A TWO-PHASE STUDY, SPONSORED BY THE FEDERAL HIGHWAY ADMINISTRATION, WAS DIRECTED AT IDENTIFYING AND DEFINING THE SAFETY AND OPERATIONAL PROBLEMS RELATED TO THE INTERACTION OF PEDESTRIANS AND VEHICLES AT INTERSECTIONS.

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ROBINSON, G.H., ERICKSON, D.J., THURSTON, G.L., AND CLARK, R.L.
HUMAN FACTORS, VOL. 14, NO. 4, AUG 1972, PP. 315-323.

THE ARTICLE DEALS WITH THE EFFECTS OF VISUAL SEARCH ON DRIVER PERFORMANCE.

ROBINSON, ETC. DID TWO EXPERIMENTS, ONE A NATURAL MEASURING SYSTEM, RECORDING VISUAL SEARCH TIMES AT AN INTERSECTION, USING UNKNOWING SUBJECTS. THE OTHER SIMULATED METHOD MEASURED PRECISELY HEAD-EYE MOVEMENT AND REACTION TIMES IN EIGHT MALE SUBJECTS AGES 20-25. IN THE SECOND EXPERIMENT THE SUBJECTS REACTION TIME IN CHANGING LANES WAS MEASURED AS WELL AS METHODS OF SEARCH.

THEY FOUND THAT RISK LEVELS IN DRIVING INCREASED DUE TO UNNECESSARY LONG VISUAL SEARCHES AND METHODS OF SEARCH BY THE DRIVER.

THE IMPLICATIONS ARE THAT HIGHWAY DESIGN, AND ESPECIALLY CAR DESIGN ARE IMPORTANT FACTORS IN THE ACQUISITION OF VISUAL INFORMATION. IMPROVEMENT OF THESE COULD DECREASE RISK IN DRIVING.

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RUCH, C.R., STACKHOUSE, D.E., AND ALBRIGHT, D.J., JR.
AUTOMOBILE ACCIDENTS OCCURING IN A MALE COLLEGE POPULATION.
AMERICAN COLLEGE HEALTH ASSOCIATION JOURNAL, VOL. 18, APR 1970, PP. 308-312.

IN THIS STUDY, 46 OF 225 STUDENTS (25%) RESPONDED THAT THEY FELT A DISTRACTING OCCURENCE HAD PLAYED A CAUSATIVE ROLE IN THE ACCIDENT. TWO MOST IMPORTANT TYPES OF DISTRACTION WERE CONVERSATION WITH A COMPANION AND ATTENTION DIVERTED TO PASSING MEMORY (11 CASES). LESS IMPORTANT WERE DISTRACTIONS SUCH AS SEARCHING FOR DEFROSTER, CHECKING SPEEDOMETER, ETC.

PERHAPS LESS EXPECTED WAS THE REPORTING OF DISTRACTION AS THIRD MOST FREQUENTLY MENTIONED CAUSATIVE FACTOR. THE TYPES OF DISTRACTION NOTED IN THIS STUDY ARE SELDOM MENTIONED AT THE SCENE OF THE ACCIDENT, FOR OBVIOUS REASONS, AND THEREFORE DO NOT APPEAR IN MANY STATISTICAL PRESENTATIONS.

THE AUTHORS FELT THAT THE ROLE OF DISTRACTION WAS SIGNIFICANT AND SHOULD BE EMPHASIZED.

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SAENZ, N.E., AND RICHE C.V. JR.
SHAPE AND COLOR AS DIMENSIONS OF A VISUAL REDUNDANT CODE.
HUMAN FACTORS, VOL. 16, NO. 3, JUNE 1974, PP. 307-312.

THIS STUDY INVESTIGATES THE SEARCH TIME FOR SHAPE AND COLOR USED SEPARATELY AND REDUNDANTLY FOR FOUR TARGET SHAPES AND FOUR TARGET COLORS IN BACKGROUNDS MADE UP OF 6 DIFFERENT SHAPES, COLORS OR SHAPE - COLOR PAIRINGS.

24 MALE SUBJECTS WHO HAD BEEN TESTED FOR COLOR VISION WERE RANDOMLY ASSIGNED TO THREE CODING CONDITIONS: COLOR; SHAPE AND REDUNDANCY. THEY WERE SHOWN 16 DISPLAYS ON A DISPLAY PANEL AND ASKED TO PICK OUT 6 TARGETS EACH TIME FROM AMONG 36 BACKGROUND OBJECTS WHICH VARIED FROM TRIAL TO TRIAL DEPENDING ON THE CODING CONDITION. EVERY POSSIBLE FACTORIAL COMBINATION OF THE 4 SHAPE LEVELS, 4 COLOR LEVELS AND 3 CODE LEVELS WERE UTILIZED (INDEPENDENT VARIABLES) SEARCH TIME WAS. THE DEPENDENT VARIABLE.

RESULTS:

1) SEARCH TIME FOR GREEN WAS LONGER THAN ANY OTHER COLOR.
2) TRIANGLES VS. CIRCLES WAS SIGNIFICANT WITH TRIANGLES HAVING THE GREATER SEARCH TIME.

IN THIS EXPERIMENT THE COLOR AND REDUNDANT CODES WERE EQUALLY EFFECTIVE AS OPPOSED TO THE SHAPE CODE WHICH PROVED TO BE LEAST EFFECTIVE AT LESSENING SEARCH TIME. (THE CODING CONDITION SERVED AS A DESCRIPTION OF THE STIMULUS BACKGROUND FROM WHICH THE TARGET MUST BE SELECTED). WHILE THE COLOR CODE WAS EFFECTIVE, THIS WAS LESSENED WHEN THE TARGET AND THE ADJACENT BACKGROUND WERE SIMILAR IN COLOR (EG. GREEN AND YELLOW GREEN). THE SHAPE CODE WAS THOUGHT TO BE LESS EFFECTIVE BECAUSE IT MAY BE INHERENTLY MORE DIFFICULT TO DIFFERENTIATE AS QUICKLY AS COLOR OR REDUNDANCY. THERE WAS NO DATA BASED HYPOTHESIS OFFERED FOR THIS HOWEVER.

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SCHROEDER, S.R., EWING, J.A., AND ALLEN, J.A.
COMBINED EFFECTS OF ALCOHOL WITH METHARPYRILENE AND CHLORDIAZEDOZIDE ON DRIVER EYE MOVEMENTS AND ERRORS.

THIS ARTICLE DEALS WITH THE COMBINATION OF ALCOHOL AND DRUGS ON DRIVER PERFORMANCE.

THIRTY HEALTHY MALE STUDENTS SOLICITED BY NEWSPAPER ADVERTISEMENT TRACKED ON AETNA TRAINING FILM IN A DRIVING SIMULATOR AFTER ADMINISTRATION OF COMBINATIONS OF ALCOHOL, LIBRIUM (CHLORDIA-DEPOXIDE), AND METHAPYRILENE OR COMBINATIONS OF ANY OF THE 3 DRUGS WITH A PLACEBO. THE SUBJECTS EYE MOVEMENTS WERE RECORDED WITH AN EYE MOVEMENT MONITOR.

ALTHOUGH NONE OF THE COMBINATIONS PRODUCED SIGNIFICANT INCREASES IN DRIVING ERRORS, DRIVER EYE MOVEMENTS WERE AFFECTED. THE MEAN PERCENTAGE OF DRIVING ERRORS WAS 33+ (ERRORS HAVING BEEN DEFINED AS A SUBJECT≠S NOT RESPONDING WITH THE SIMULATOR WITHIN 20 SECONDS AFTER AN EVENT OCCURED ON FILM). ALCOHOL SUPPRESSED EYE MOVEMENT FREQUENCY AND RESTRICTED THE USUAL FIELD OF VIEW WHILE LIBRIUM INCREASED EYE MOVEMENT FREQUENCY AND A COMBINATION RESULTED IN INTERMEDIATE FREQUENCY. METHAPYRILENE DID NOT AFFECT EYE MOVEMENT FREQUENCY BUT HAD AN ANTAGONISTIC EFFECT ON SUPPRESSION OF SACCADES BY ALCOHOL. THE EFFECT OF DRUGS ON EYE MOVEMENT WAS SIGNIFICANT. IT WAS ALSO FOUND THAT THE TUNNEL VISION EFFECT (MOST LIKELY DUE TO ALCOHOL) WAS SIGNIFICANT IN BEING RELATED TO DRIVING ERRORS.

THIS STUDY SHOWS THAT MANY DRUGS WORK TOGETHER WITH ALCOHOL TO AFFECT DRIVING PERFORMANCE AND EYE MOVEMENT PARAMETERS ARE A SENSITIVE MEASURE OF THESE EFFECTS.

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SENDER, J.W.
THE ESTIMATION OF OPERATOR WORKLOAD IN COMPLEX SYSTEMS.
SYSTEMS PSYCHOLOGY. MCGRAW-HILL BOOK CO., NEW YORK, 1970,
PP. 207-216.

IN THIS PAPER, THE CONCEPTS OF TIME DEMANDS, ERROR AND INFORMATION ARE DISCUSSED IN RELATION TO THE DESIRED OUT COME - TO BE ABLE TO PREDICT WORKLOADS PLACED ON HUMAN OPERATORS BY SOME WELL-DEFINED SYSTEM PERFORMING SOME WELL-DEFINED MISSION. (I.E. PILOTING JETS OR DRIVING AUTOMOBILES). A SYSTEMS THEORY APPROACH IS USED IN THIS REVIEW OF OPERATOR WORKLOAD EXPERIMENTS, AND AMONG THE TOPICS DISCUSSED ARE: MEANS OF WORKLOAD ESTIMATION, DEFINITIONS OF OPERATOR LOADING TASKS, AN APPROACH TO SYSTEMS DESIGN; AND 4 MODELS OF VISUAL SAMPLING BEHAVIOR (PERIODIC AND CONDITIONAL APERIODIC SAMPLINGS; TRANSITION PROBABILITIES [LINK VALUES]; AND VALIDATION STUDIES). USING JET INSTRUMENT PANELS AS EXAMPLES, SENDERS DEMONSTRATES THE VARIOUS APPROACHES TO MAN-MACHINE SYSTEMS ANALYSIS, WITH THE ASSUMPTION THAT AN OPERATOR IS A SINGLE-CHANNEL DEVICE. UPON WHICH DEMANDS ARE MADE BY INFORMATION SOURCES IN THE ENVIRONMENT. THE CONCEPTS OF QUEVES AND SIMULTANEOUS ATTENDING ARE ALSO DISCUSSED. THE AUTHOR SPECULATES THAT THE ABILITY TO CALCULATE THE STATISTICS OF VISUAL BEHAVIOR WILL PERMIT THE EVALUATION OF INSTRUMENT DESIGNS IN OPERATIONAL SITUATIONS BY COMPARING THE PREDICTED AND OBSERVED BEHAVIORS.

THE AUTHOR BELIEVES THAT THE RATIONAL AND PROCEDURE PROPOSED IN THIS TRANSITION MODEL MAY BE GENERALIZED TO A WIDE VARIETY OF SYSTEMS. THIS REFERENCE MAY BE USED CONCERNING DRIVER≠S ATTENTIONAL DISTRACTIONS.

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SNYDER, J.C.
ENVIRONMENTAL DETERMINANTS OF TRAFFIC ACCIDENTS: AN ALTERNATE MODEL.
TRANSPORTATION RESEARCH RECORD, 1974, NO. 486, PP. 11-18.

THIS STUDY IS CONCERNED WITH IDENTIFICATION AND QUANTIFICATION OF ENVIRONMENT OF DETERMINANTS OF TRAFFIC ACCIDENTS AND WITH THE CONSTRUCTION OF A CONCEPTUAL MODEL OF TRAFFIC ACCIDENTS BASED ON ENVIRONMENTAL FACTORS.

DEPENDENT VARIABLES INCLUDE ACCIDENT NUMBERS AND RATE (PER MILLION VEHICLE MILES). INDEPENDENT VARIABLES INCLUDE PHYSICAL CHARACTERISTICS OF THE ROAD, ROAD FRONTAGE (ADJACENT LAND USE), AND PHYSICAL AND SOCIAL CHARACTERISTICS OF THE REGION. DATA ARE TAKEN FROM A SAMPLE OF 135 ROAD SEGMENTS, EACH 2 MILES LONG, IN OAKLAND COUNTY, MICHIGAN. MANY ENVIRONMENTAL CHARACTERISTICS ARE REPRESENTED. AUTOMATIC INTERACTION DETECTION, MULTIPLE CLASSIFICATION ANALYSIS, AND MULTIPLE REGRESSION TECHNIQUES ARE USED TO CONSTRUCT A SERIES OF PREDICTIVE MODELS.

ANALYSIS SHOWS THAT THE NUMBER OF ACCIDENTS ON A ROAD SEGMENT IS BEST PREDICTED FROM THE TYPE OF ROAD, THE INTENSITY OF ROAD FRONTAGE DEVELOPMENT, AND THE PERCENTAGE OF THE POPULATION BETWEEN THE AGES OF 16 AND 24. INSPECTION OF THE FORMULATED MODELS SUGGESTS A CONCEPTUAL MACROMODEL.

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SUMMULA, HEIKKI, AND NÄÄTÄNEN, RISTO.
PERCEPTION OF HIGHWAY TRAFFIC SIGNS AND MOTIVATION.
JOURNAL OF SAFETY RESEARCH, 1974, VOL. 6, NO. 4, PP. 150-154.

THE PURPOSE OF THIS EXPERIMENT WAS TO DEMONSTRATE THAT MOTIVATION IS A MORE IMPORTANT FACTOR THAN PERCEPTION IN THE DRIVER≠S ABILITY TO DETECT TRAFFIC SIGNS.

SUBJECTS WERE ASKED TO DRIVE A CAR AS SAFELY AS POSSIBLE OVER A TWO LANE HIGHWAY ROUTE, WITH RATHER HEAVY TRAFFIC, OBEYING ALL TRAFFIC RULES AND TO NAME EVERY TRAFFIC SIGN THEY SAW. AN EXPERIMENTER SAT IN THE BACK TO RECORD MISREPORTED OR UNREPORTED SIGNS AND ALL TRAFFIC VIOLATIONS. THERE WERE URBAN, AND NON-URBAN NON-INTERSECTION, AREAS IN THE ROUTE.

ABOUT 97↓ OF THE SIGNS OVER THE WHOLE ROUTE WERE REPORTED. ALMOST ALL SIGNS IN THE NON-URBAN, NON-INTERSECTION AREAS WERE REPORTED BUT THE PERCENTAGE OF UNREPORTED SIGNS ROSE TO 8.95↓ FOR THE URBAN SECTIONS.

THE MOST FREQUENTLY UNREPORTED SIGNS WERE USUALLY LOCATED AT INTERSECTIONS AND OTHER DIFFICULT PLACES. SUMMALA USED A WIDE AND VARIED ROUTE, BUT ONLY USED 9 SUBJECTS.

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TAYLOR, J.I., MCGEE, H.W., DEGUIN, E.L., AND HOSTETTER, R.S.
ROADWAY DELINEATION SYSTEMS.
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT, 1972, NO. 130, 349 PGS.

THE PURPOSE OF THIS STUDY WAS TO EVALATE THE EFFECTIVENESS OF DIFFERENT DELINEATION SYSTEMS IN SPECIFIC ROADWAY SITUATIONS. TWO STUDIES INCLUDED: 1) LAB STUDY TO EVALUATE THE DEGREE O RESISTANCE TO CLUTTER OF VARIOUS DELINEATION TREATMENTS OF EXIT RAMPS, CURVES, LANE DROPS AND STOP APPROACHES.
2) MEAN SPOT SPEEDS WERE TAKEN AT POINTS 200 AND 500 FEET BEFORE THE STOP SIGN IN FOUR DELINEATION CONDITIONS AT THE SAME SITE

RESULTS:

1) ALL SYSTEMS SHOWED A HIGH RESISTANCE TO CLUTTER, BUT THIS MAY HAVE BEEN THE RESULT OF SEVERAL CONFOUNDING FACTORS IN THE STUDY, SUCH AS LEARNING.
2) CRYSTAL POST DELINEATORS WERE MORE VULNERABLE TO EFFECTS OF CLUTTER THAN AMBIC ON CURVES. NO DIFFERENCES WERE FOUND FOR LANE DROP OR STEEP APPROACH.
3) NO STATISTICAL DIFFERENCES WERE FOUND BETWEEN CONDITIONS. ON THE AVERAGE CRYSTAL POST DELINEATORS WERE THAN BAE CONDITION AND RED DELINEATORS IN REDUCING SPEED VARIABILITY.

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TAYLOR, M.M.
DETECTABILITY THEORY AND THE INTERPRETATION OF VIGILANCE DATA.
ACTA PSYCHOLOGICA, VOL. 27, 1967, PP. 390-399.

DETECTION THEORY AND ITS RELATION TO VIGILANGE DATA IS DISCUSSED USING THE CONCEPT OF SUBJECTIVE PROBABILITY. IN THIS PAPER THE CONCEPT OF LIKELIHOOD RATIO IS CONSIDERED AS AN INTERPRETIVE CONVENIENCE, RATHER THAN A CONCEPTUAL NECESSITY, AND THIS CONCEPT IS USED TO DEFINE THE ROC CURVES.

IN THIS DISCUSSION OF THE MECHANICS OF DETECTION, IT WAS CONCLUDED THAT IN VIGILANCE EXPERIMENTS, THE ROC MAY BE EXPECTED TO SHOW MORE OR LESS SEVERE SKEW, WHICH IN TURN AFFECTS THE INTERPRETATION OF THE VARIOUS INDICES OF DETECTION BEHAVIOR. OTHER ITEMS DISCUSSED IN THE PAPER INCLUDE: DISCRIMINATION AND SUBJECTIVE PROBABILITY, LIKELIHOOD RATIOS, PROPERTIES OF ROC CURVES (IN VIGILANCE) AND SKEWED ROC CURVES AND THEIR INTERPRETATION.

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THORPE, J.C.
ACCIDENT RATES AT SIGNALIZED INTERSECTIONS.
AUSTRALIAN ROAD RESEARCH BOARD, VOL. 4, PART 1, 1968, PP. 995-1004.

THORPE≠S STUDY SHOWS THE RESULTS OF AN INVESTIGATION CARRIED OUT BY THE TRAFFIC COMMISSION OF VICTORIA TO DETERMINE THE MEAN ACCIDENT RATE AT HEAVILY TRAVELLED CROSS INTERSECTIONS IN THE MELBOURNE METROPOLITON AREA.

THE BASIC INFORMATION USED IN THE STUDY WERE (A) 12 HOUR 7:00AM - 7:00PM TRAFFIC COUNTS CARRIED OUT IN 1963 AT SIGNALIZED INTERSECTIONS IN THE MELBOURNE METROPOLITON AREA EXCEPT THOSE INSIDE THE CITY OF MELBOURNE. ALSO INCLUDED WERE THOSE IN THE BOUNDARY OF MELBOURNE CITY AND ABUTTING MUNICIPALITIES, (B) 24 HOUR ACCIDENT INFORMATION FOR THE PERIOD 1961 TO 1965 INCLUSIVE EXTRACTED FROM THE COMMISSIONS ACCIDENT RECORD. A FEW UNSIGNALIZED INTERSECTIONS WERE ALSO STUDIED.

THE MEAN RATE AT 124 SIGNALIZED INTERSECTIONS WAS 6.22 EQUAVALENT PERSONAL INJURY ACCIDENTS PER 10 MILLION VEHICLES THROUGH AN INTERSECTION. THE MEAN RATE AT 16 UNSIGNALIZED INTERSECTIONS WAS 5.68. (PERSONAL INJURY ACCIDENTS AND FATAL ACCIDENTS ARE EQUATED EVENLY. PROPERTY DAMAGE ACCIDENTS ARE FIGURED IN AS 1/4 AT A PERSONAL INJURY ACCIDENT).

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VERSACE, J.
FACTOR ANALYSIS OF ROADWAY AND ACCIDENT DATA.
HIGHWAY RESEARCH BOARD BULLETIN, 1960, NO. 246, PP. 24-32.

THIS STUDY EXAMINED THE DEGREE OF COMPLEXITY OF TRAFFIC ENVIRONMENT AND ACCIDENTS.

THEY USED ACCIDENT STATISTICS ON SECTIONS OF TWO-LANE OREGON HIGHWAYS. REGRESSION EQUATIONS WERE DEVELOPED AS WELL AS FACTOR ANALYSIS PERFORMED.

RESULTS:

1) ACCIDENTS OCCUR MOST FREQUENTLY IN AREAS WHERE THERE ARE MORE CARS AND WHERE TRAFFIC FLOW INTERFERED WITH BY INTERSECTIONS AND DRIVEWAYS.
2) ACCIDENT FREQUENCY WAS PROPORTIONAL TO THE LOAD OR RATE OF DEMAND PLACED ON DRIVER≠S ABILITY TO PERCEIVE ND COPE WITH THE SITUATION.

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WALKER, F.W., AND ROBERTS, S.E.
INFLUENCE OF LIGHTING ON ACCIDENT FREQUENCY AT HIGHWAY INTERSECTIONS.
TRANSPORTATION RESEARCH RECORD, 1976, NO. 562, PP. 73-78.

THIS EXPERIMENT SOUGHT TO DETERMINE THE EFFECT OF NIGHT LIGHTING ON ACCIDENT RATES AT INTERSECTIONS.

THE SIX YEAR STUDY LOOKED AT INTERSECTIONS WHERE IT WAS POSSIBLE TO DETERMINE BY ESTIMATION TRAFFIC RECORD THREE YEARS BEFORE LIGHTING AND THREE YEARS AFTER. THE ACCIDENTS WERE REVIEWED AND TIMES OF ACCIDENTS WERE NOTED. TIMES OF SUNRISE AND SUNSET WERE NOTED TO DETERMINE TIME OF DAY OF OCCURENCE. 27% OF THE TRAFFIC OCCURED AT NIGHT,

SIX LEVELS OF TRAFFIC WERE DIVIDED INTO TWO LEVELS OF LIGHTING, (LIGHTS AND NO LIGHTS). AN ANALYSIS OF VARIANCE WITH THE NUMBER OF NIGHT ACCIDENTS AS THE DEPENDENT VARIABLE. GROUPS OF INTERSECTIONS WERE DIVIDED INTO THOSE WITH: (# OF CARS) 1. LOWER THAN 2500, 2. 2500-2999, 3. 3000-3499, 4. 3500-4399, 5. 4400-5699. 6. 5700 AND HIGHER.

IN THIS INVESTIGATION THE RATE WAS REDUCED TO 1.89 TO .91 ACCIDENTS PER MILLION VEHICLES. LITTLE EFFECT WAS NOTED WITH VOLUMES UNDER 3500. IN GENERAL, LIGHTING SIGNIFICANTLY REDUCED THE NUMBER OF NIGHT ACCIDENTS, (WITH AVERAGE DAILY TRAFFIC ABOVE 3500). THE STUDY INDICATES THAT LIGHTING CHIEFLY ALLOWS DRIVER≠S MEET ADDITIONAL DRIVING DEMANDS WITH NO LOSS IN SAFETY.

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WALKER, J.T.
LYTHGUE≠S VISUAL STEROPHENOMENON IN THE NATURAL ENVIRONMENT: A POSSIBLE FACTOR IN AIR AND HIGHWAY ACCIDENTS.
HUMAN FACTORS, 1974, VOL. 16, NO. 2, PP. 134-138.

THIS IS A STUDY OF THE LYTHGUE EFFECT IN THE NATURAL ENVIRONMENT. LYTHGUE DISCOVERED THAT THE PATH OF A HORIZONTALLY MOVING OBJECT APPEARED DISTORTED IN DEPTH WHEN THE OBJECT WAS VIEWED BINOCULARLY WITH A BRIGHT LIGHT SHINING IN ONLY ONE EYE. SHINING A LIGHT IN ONE EYE PRODUCES A DIMMER IMAGE IN THAT EYE THROUGH THE MECHANISM OF BRIGHTNESS CONTRAST BUT THE DIMMER IMAGE HAS THE SHORTER VISUAL LATENCY, SOMETHING THAT LYTHGUE CONSIDERED UNEXPECTED. THIS DIFFERENCE BETWEEN IMAGE LATENCIES TRANSLATES INTO AN APPARENT SPATIAL DIFFERENCE BETWEEN IMAGE POSITIONS - BINOCULAR DISPARITY - RESULTING IN AN APPARENT DEPTH DISPLACEMENT OF THE MOVING OBJECT. IN THE NATURAL VISUAL ENVIRONMENT, ONE EYE CAN BE LIGHTED BY THE SUN WHILE THE OTHER EYE IS SHADED BY THE NOSE, THUS POSSIBLY CAUSING DISTORTIONS IN THE APPARENT PATHS OF AIRPLANES OR OF GROUND TRAFFIC SUCH AS TRAINS MOVING AT RIGHT ANGLES ACROSS THE PATH OF AN OBSERVER≠S AUTOMOBILE.

ACCORDING TO WALKER, THERE HAVE BEEN NO REPORTS OF ANY CONSIDERATION OF LYTHGUE≠S EFFECT AS A POSSIBLE FACTOR IN AIR OR HIGHWAY ACCIDENTS. IN DAYTIME VIEWING CONDITIONS, THERE ARE MANY DISTANCE CUES ASSOCIATED WITH TRAFFIC MOVING ON THE GROUND (I.E. INTERPOSITION, LINEAR PERSPECTIVE, ETC.). HOWEVER, AT NIGHT, WHEN DISTANCE CUES ARE GREATLY REDUCED, LYTHGUE≠S DISTORTIONS MAY BECOME IMPORTANT. IT IS HOPED THAT WORKERS CONCERNED WITH AIR AND HIGHWAY SAFETY WILL CONSIDER THE POSSIBLE IMPLICATIONS OF THESE OBSERVATIONS.

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WALTON, N.E., AD MESSER. C.J.
WARRANTING FIXED ROADWAY LIGHTING FROM A CONSIDERATION OF DRIVER WORK-LOAD.
TRANSPORTATION RESEARCH RECORD, 1974, NO. 502, PP. 9-21.

THIS PAPER EVALUATES WHETHER EFFICIENT AND EFFECTIVE VEHICLE CONTROL IS PROBABLE WITHIN A GIVEN NIGHT DRIVING ENVIRONMENT.

A WARRANTING SCHEME FOR ROADWAY LIGHTING IS DEVELOPED BASED ON WHETHER EFFICIENT AND EFFECTIVE VEHICLE CONTROL CAN BE ACHIEVED. DRIVER VISUAL WORK-LOAD IS USED AS THE MEASURE OF EFFECTIVENESS FOR VEHICLE CONTROL. DRIVER TASK LEVELS ARE DEFINED FOR THE COMPUTATION OF WORK-LOAD OR INFORMATION DEMAND. THE TASK LEVELS ARE POSITIONAL, PRIMARILY ROUTINE SPEED AND LANE POSITION CONTROL; SITUATIONAL, CHANGES IN SPEED, DIRECTION OF TRAVEL OR POSITION AS A RESULT OF CHANGES IN SITUATIONS, AND NAVIGATIONAL, SELECTING AND FOLLOWING A ROUTE. INFORMATION DEMAND IS DEFINED AS THE TIME IN SECONDS REQUIRED TO FULFILL A SEQUENCE OF POSITIONAL, SITUATIONAL, NAVIGATIONAL, AND REDUNDANT POSITIONAL INFORMATION SEARCHES. INFORMATION SUPPLY IS DEFINED TO BE THE TIME IN SECONDS REPRESENTING THE VISIBILITY DISTANCE AHEAD FOR A GIVEN OPERATING SPEED.

IT WAS FOUND THAT WHEN INFORMATION DEMAND EXCEEDS INFORMATION SUPPLY WITHOUT ROADWAY LIGHTING, THEN ROADWAY LIGHTING IS ASSUMED TO BE WARRANTED.

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WANDERER, U.N., AND WEBER, H.M.
FIRST RESULTS OF EXACT ACCIDENT DATA ACQUISITION ON SCENE.
INTERNATIONAL CONFERENCE ON OCCUPANT PROTECTION. 3RD PROCEEDINGS, NEW YORK, 1974, PP. 80-94.

THIS STUDY CONSISTED OF AN INTERDISCIPLINARY TEAM OF: 2 SURGEONS, 2 ENGINEERS, 1 PSYCHOLOGIST, AND 1 PATHOLOGIST.

OUT OF 127 CASES EXTERNAL DISTRACTION WAS RECORDED IN 12 CASES (9.5%). THE CAUSES OF THE DISTRACTION WAS DUE TO OTHER ROAD USERS, BUILDUPS, ADVERTISEMENTS, CAR RADIOS, CONVERSATONS WITH PASSENGERS ETC.

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WINKEL, G.H., MALEK, R., AND THIEL, P.
COMMUNITY RESPONSE TO THE DESIGN FEATURES OF ROADS: A TECHNIQUE FOR MEASUREMENT.
HIGHWAY RESEARCH RECORD, 1970, NO. 395, PP. 133-145.

THIS EXPERIMENT STUDIED SUBJECTS RESPONSES TO SLIDES WHICH HAD BEEN PHOTOGRAPHICALLY TRANSFORMED TO SHOW REMOVAL OF 1) BILLBOARDS, 2) UTILITY POLES AND OVERHEAD WIRES, 3) BOTH 1 AND 2, 4) 1 AND 2 N-PREMISES SIGNS.

THE METHODOLOGY INCLUDED A SEMANTIC DIFFERENTIAL, AN ATTITUDE QUESTIONAIRE, AND AN EYE-MOVEMENT CAMERA.

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WITT, HAROLD, AND HOYOS, CARL G.
ADVANCE INFORMATION ON THE ROAD: A SIMULATOR STUDY OF THE EFFECTS OF ROAD MARKINGS.
HUMAN FACTORS, VOL. 18, NO. 6, DEC 1976, PP. 521-532.

THIS STUDY CONSIDERED THE DANGERS INVOLVED IN DRIVING ON CURVED ROADS. ROAD SIGNS HAVE NOT PROVEN TO BE EFFECTIVE AT FOREWARNING ONCOMING DRIVERS OF A CURVED ROAD. THE ACCIDENT RATE FOR CURVED ROADS HAS BEEN EXTREMELY HIGH.
THE OBJECT OF THIS STUDY WAS TO EXPLORE THE POSSIBILITIES OF GIVING ADVANCE INFORMATION CONCERNING THE FEATURES OF A ROAD.

RESULTS:

1) SUBJECTS WERE ABLE TO RECEIVE AND PROCESS THE ADVANCE INFORMATION.
2) THE PREDICTIVE CHARACTER OF THE INFORMATION WAS RECOGNIZED BY THE SUBJECTS.
3) ADVANCE INFORMATION CONTRIBUTED TO A MODIFICATION OF DRIVING ACTIONS CRITICAL TO SAFE DRIVING ON WINDING ROADS.

THE STUDY DID NOT COMPARE THE EFFECTS OF THE CODE VS. THE TRADITIONAL ROAD SIGNS. DUE TO THE NATURE OF SIMULATORS THE PROBABILITY THAT A DRIVER WOULD IGNORE THE SIGN IS LOWERED BY SIMULATOR DRIVING, AS THERE IS LESS STIMULI IN THE FABRICATED ENVIRONMENT.

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WOLTMAN, H.L., AND AUSTIN, R.L.
SOME DAY AND NIGHT VISUAL ASPECTS OF MOTORCYCLE SAFETY.
TRANSPORTATION RESEARCH RECORD, 1974, NO. 502, PP. 1-8.

THIS ARTICLE CONCERNS DAY AND NIGHT VISIBILITY AND COMPARES FLOURESCENT AND CONVENTIONAL PIGMENTS AGAINST RESPECTIVE BACKGROUNDS FOR USE IN MOTORCYCLE SAFETY.

VISUAL AREA TESTS WERE DONE WITH THE RIDER ASTRIDE THE MOTORCYCLE AND SEPARATE FROM IT.

IT WAS FOUND THAT THE VISUAL AREA OF THE MOTORCYCLE AND RIDER IS APPROXIMATELY 1/3 THAT OF A CONVENTIONAL AUTOMOBILE. THE AUTOMOBILE IS THE SIZE HAZARD TO WHICH THE MOTORIST MOST FREQUENTLY AND SUCCESSFULLY ACCOMODATES. BY IMPROVING PERCEPTUAL AIDS SUCH AS USING HIGHLY VISIBLE AND CONTRASTING COLORS (SUCH AS FLUORESCENT ORANGE), THE MOTORIST MIGHT MORE SUCCESSFULLY COPE WITH THE SMALLER MOTORCYCLE HAZARD. AT NIGHT, IF THE MOTORCYCLE AND OPERATOR WERE BOTH REFLECTORIZED, DEPTH PERCEPTION WOULD BE ENHANCED.

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WOLTMAN, H.L.
REVIEW OF VISIBILITY FACTORS IN ROADWAY SIGNING.
HIGHWAY RESEARCH BOARD SPECIAL REPORT, NO. 134, 1972 PP. 28-36.

THIS PAPER REVIEWS THE RESULTS OF SIGNING RESEARCH LITERATURE OVER THE PAST HALF CENTURY.
THE IMPLICATIONS OF THE LITERATURE ARE: SIGN PERFORMANCE IS DEPENDENT UPON LEGIBILITY AND ATTENTION OR TARGET VALUE. THE IMPORTANT FACTORS OF LEGIBILITY DISTANCE ARE: BETTER HEIGHT, WIDTH, SPACING, CONTRAST AND BRIGHTNESS. THESE FACTORS INTERACT AND INFLUENCE THE OTHERS. TARGET VALUE OF SIGNS ARE IMPORTANT IN PROVIDING SUFFICIENT TIME FOR THE DRIVER TO PROCESS INFORMATION AND RESPOND TO IT CORRECTLY. MAJOR FACTORS AFFECTING TARGET VALUE ARE: SIGN COLOR AND BRIGHTNESS, WHICH PRODUCE CONTRAST WITH THE NAUTRAL BACKGROUND. LOCATION, NUMBER OF SIGNS, READING HABITS, SEARCH PROCEDURE AND MENTAL SIT ALSO AFFECT ATTENTION OR PRIORITY VALUE. LUMINANCE IS IMPORTANT FOR NIGHT DRIVING. PROPER LUMINANCE IS DEPENDED ON HEADLIGHT DISTRIBUTION PATTERN, SIGN OFFSET, MATERIAL EFFICIENCY, AND LETTER SIZES.
WOLTMAN CONCLUDES THAT SIGNS WILL REMAIN THE PRIMARY CHANNEL FOR COMMUNICATION BECAUSE 1) DRIVER≠S EXPECT TO RECEIVE INFORMATION FROM SIGNS, 2) SIGN PANELS AND SUPPORTS ALREADY EXIST AND THEREFORE MAKE IT LESS EXPENSIVE THAN CHANGING TO A NEW SYSTEM, 3) PERSONNEL, ORGANIZATIONS, TECHNOLOGY AND EQUIPMENT NECESSARY TO IMPLEMENT ANY SIGN SYSTEM ALREADY EXISTING.

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WOODS, D.L., ROWAN, N.J., AND JOHNSON, J.H.
A SUMMARY REPORT: SIGNIFICANT POINTS FROM THE DIAGNOSTIC FIELD STUDIES.
TEXAS TRANSPORTATION INSTITUTE, TEXAS A^M UNIVERSITY, COLLEGE STATION, RES. REPORT 606-4, 1970.

THE PURPOSE OF THIS EXPERIMENT WAS TO IDENTIFY DEFICIENCES IN THE PRESENT SYSTEM OF SIGNING, DELINIATION AND MARKING.
THE METHOD USED WAS A DIAGNOSTIC TEAM STUDY TECHNIQUE TO EVALUATE VISUAL COMMUNICATIONS ON FREEWAYS, ARTERIAL STREETS AND TWO-LANE HIGHWAYS.
THE EXPECTANCIES OF DRIVERS SHOULD BE CONSIDERED. DRIVERS EXPECT GREEN BACKGROUNDS FOR FREEWAY DIRECTIONAL SIGNING AND OVERLOOK SIGNS WHERE THE BACKGROUND IS A DIFFERENT COLOR. DIAGRAMATIC SIGNS ARE HELPFUL FOR DIFFICULT OR UNUSUAL GEMETRIC DESIGNS. THERE IS A NEED FOR BETTER IDENTIFICATION OF FREEWAY ENTRANCE RAMPS. URBAN AND ARTERIAL ROAD SIGNING WAS MUCH WORSE THAN FREEWAY SIGNING BECAUSE OF THE LACK OF CONTINUITY OR COMPLETE ABSENSE OF SIGNING. PAVEMENT MARKINGS (I.E. EDGELINES OR YELLOW LINES) ARE PARTICULARLY IMPORTANT ON A TWO-LANE HIGHWAY WHERE DRIVERS ARE DEPENDENT ON ROAD GEOMETRY FOR GUIDANCE.

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LABORATORY DATA
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THE DATA IN THIS FILE ARE STORED AS FOLLOWS:

1. THE REACTION TIMES FOR EACH SUBJECT TAKE 3 CARDS (LINES) AND ARE FORMATED 16F4.0 ON EACH CARD, PRODUCING 48 REACTION TIMES. EACH DATA POINT REPRESENTS THAT SUBJECTS REACTION TIME TO A SLIDE WITH SPECIFIC CHARACTISTICS DEPENDING UPON WHAT VALUE EACH OF 3 VARIABLES TOOK.

   VARIABLE ONE (PROXIMITY) ----- PROXIMATE (24), DISTANT (24)

   VARIABLE TWO (NUMBER OF DISTRACTORS) ----- 2 (12), 4 (12), 6 (12), 10 (12)

   VARIABLE THREE (COLOR OF DISTRACTORS) ------ ALL RED (8) RED AND ORANGE (8), ALL ORANGE (8), RED AND COOL (8), ORANGE AND COOL (8), ALL COOL (8)

2. THE VARIABLES ARE NESTED AS:

   (VARIABLE ONE (VARIABLE TWO (VARIABLE 3)))

   SO THAT THE THIRD REACTION TIME ON CARD 2 (27TH FOR THAT SUBJECT) WOULD BE TO A SLIDE THAT WAS:

   1. DISTANT - VARIABLE ONE
   2. 2 DISTRACTORS - VARIABLE TWO
   3. ALL ORANGE - VARIABLE THREE

011	615	644	672	580	553	472	646	469	608	554	571	556	447	739	565	436
012	704	629	589	602	678	521	747	670	479	495	526	703	594	418	625	533
013	361	401	569	507	546	661	607	751	569	504	553	841	619	509	606	491
021	593	501	540	681	545	490	469	502	494	667	478	562	790	513	590	527
022	492	597	475	720	449	560	434	461	515	506	624	451	536	478	464	500
023	476	660	484	517	408	478	417	502	471	478	736	527	458	488	428	460
031	458	485	531	515	479	474	448	439	506	496	523	621	527	561	416	515
032	537	530	466	695	527	741	509	572	475	566	442	381	437	487	464	419
033	460	396	440	429	526	473	488	449	387	433	442	584	475	443	455	730
041	608	555	541	538	484	529	574	489	495	613	563	502	546	651	517	480
042	588	626	576	511	561	582	488	596	516	499	448	457	683	428	599	572
043	469	491	588	550	578	562	534	581	559	581	518	519	509	556	528	478
051	493	520	543	623	465	605	554	425	564	558	776	473	483	692	597	575
052	514	763	569	701	499	561	601	585	516	571	482	742	564	477	533	488
053	528	472	478	495	723	628	474	753	429	547	425	581	522	552	481	519
061	803	805	625	1372	1168	719	899	691	881	793	1254	1348	636	1028	757	648
062	740	892	1084	1184	564	925	661	1164	710	837	688	824	773	686	756	831
063	655	695	813	865	752	732	504	923	698	1027	815	1080	752	743	987	904
071	652	618	577	645	690	649	658	534	660	502	618	637	533	566	671	496
072	746	667	681	724	544	552	574	656	491	686	463	621	521	501	667	610
073	465	494	679	490	580	726	536	683	689	675	725	656	633	684	634	562
081	584	578	775	783	619	696	646	590	585	900	662	648	1079	851	635	851
082	791	793	976	715	819	833	813	616	1179	589	751	694	699	592	694	1074
083	651	506	596	605	823	822	952	613	660	725	868	622	703	712	634	748
091	792	732	640	970	480	873	570	767	570	701	662	583	677	880	1272	567
092	982	722	544	626	719	777	874	706	705	753	476	920	741	699	847	707
093	454	600	1168	574	692	635	602	1221	755	669	1036	662	964	540	682	613
101	667	442	425	654	482	579	551	483	579	696	483	562	511	645	565	420
102	473	561	454	749	582	510	495	888	517	724	472	456	510	436	600	511
103	415	500	487	490	581	532	510	506	429	571	614	527	430	602	567	733
111	616	692	584	583	496	618	675	692	615	595	636	507	783	710	540	609
112	563	736	586	582	583	576	566	596	564	587	641	542	564	498	636	496
113	524	666	600	638	635	595	521	657	524	586	671	676	513	600	595	617
121	895	1032	850	835	1022	857	1223	742	827	900	989	921	897	950	875	825
122	1287	1327	1057	1009	923	933	848	879	848	945	774	715	693	644	1098	796
123	736	605	1234	719	1198	883	793	948	741	770	1007	890	997	909	1010	1108
131	595	497	655	744	583	547	573	501	680	540	594	486	504	561	541	509
132	548	573	575	694	505	557	617	488	495	543	498	543	472	504	578	516
133	504	438	539	446	619	588	510	558	511	532	640	592	546	543	476	611
141	433	444	465	454	515	483	537	508	518	740	493	536	553	564	447	525
142	539	682	465	579	566	521	705	443	555	418	460	447	517	470	500	438
143	534	486	626	478	488	466	470	492	464	483	508	435	446	462	567	488
151	424	456	470	516	536	473	456	567	490	633	505	554	668	504	459	554
152	515	627	528	588	774	499	577	725	626	460	559	486	524	536	513	623
153	635	619	588	568	510	613	621	476	491	548	654	495	462	544	773	531
161	588	496	498	541	528	540	570	541	623	547	529	559	511	605	602	570
162	627	646	524	685	533	482	556	520	534	506	510	507	495	460	555	602
163	539	520	620	594	465	460	568	646	459	643	611	545	549	502	500	630
171	500	615	578	546	464	569	522	479	449	539	495	478	403	506	500	434
172	553	632	481	648	615	557	518	408	541	538	413	453	428	365	942	463
173	373	411	583	434	517	444	405	519	496	494	644	486	454	576	551	497
181	600	635	770	623	638	568	705	546	603	912	728	747	501	694	583	495
182	607	811	521	583	603	609	567	560	694	878	547	623	550	557	601	623
183	425	511	546	649	640	621	646	622	629	542	597	607	592	714	500	612
191	716	497	546	750	479	706	500	462	450	636	530	572	460	466	666	337
192	726	693	483	666	695	667	600	640	440	589	470	502	419	408	641	616
193	404	431	526	434	494	581	441	638	427	768	611	527	613	721	588	673
201	614	737	691	825	624	554	627	463	622	532	724	646	467	651	556	714
202	707	693	614	873	698	676	638	515	827	718	592	506	579	504	643	612
203	492	488	636	481	774	674	698	732	621	807	541	742	691	667	581	702
211	523	517	584	725	659	571	660	509	444	639	618	619	560	579	542	446

212	554	672	630	547	468	636	448	511	687	575	498	461	449	414	450	465
213	441	419	626	508	562	439	474	583	459	586	584	592	919	621	501	620
221	537	717	560	551	527	739	597	463	449	817	548	527	444	630	695	602
222	592	636	529	581	552	525	529	513	569	441	485	528	556	486	544	640
223	453	430	619	554	468	586	501	760	617	657	601	583	576	740	564	692
231	843	460	420	529	452	479	613	461	486	528	502	483	432	630	473	427
232	461	693	486	673	458	512	498	474	388	537	473	442	357	605	483	475
233	408	392	488	424	477	621	404	464	362	493	541	509	413	556	465	522
241	618	481	535	656	463	531	530	452	528	678	729	635	411	541	538	390
242	601	671	477	644	657	580	550	533	474	602	513	510	366	396	615	510
243	361	371	601	454	474	592	526	479	482	531	711	474	493	477	490	568
251	882	505	517	663	558	558	652	519	614	550	585	547	584	572	522	557
252	607	643	721	669	709	545	567	476	535	611	511	555	518	566	554	471
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272	458	531	461	617	460	580	469	625	511	543	466	395	454	409	577	493
273	428	405	625	414	490	477	396	569	461	411	454	472	540	471	486	449
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282	920	699	776	953	581	677	529	713	471	636	480	725	644	390	863	1044
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292	510	717	724	610	557	595	536	511	541	517	476	531	522	451	482	649
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312	703	579	630	689	619	786	574	599	571	605	525	794	511	479	550	678
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332	724	621	1250	733	588	513	695	665	477	1084	479	806	442	480	770	586
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362	546	622	535	616	6 4	676	633	689	569	558	629	747	635	494	654	577
363	475	488	501	496	638	615	609	581	621	604	597	556	757	863	617	899
371	714	753	779	930	653	656	798	563	771	740	812	683	654	741	645	669
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403	458	417	446	438	519	513	373	411	495	603	389	604	432	415	422	444
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552	608	647	477	757	684	587	589	535	691	590	708	468	648	492	592	572
553	879	588	625	605	563	484	556	572	637	570	486	504	741	545	486	622
561	515	404	561	555	834	518	679	447	515	611	483	544	473	649	428	420
562	677	496	450	515	701	521	658	433	563	700	475	388	429	380	673	506
563	355	522	712	525	463	452	433	526	568	592	564	421	485	483	533	566
571	576	578	808	872	561	835	737	823	603	876	817	750	737	779	855	910
572	954	771	596	658	923	718	763	625	731	863	776	785	731	828	725	732
573	721	748	821	689	828	928	872	531	587	721	727	942	739	797	785	747

FIELD DATA
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THE DATA IN THIS FILE ARE STORED AS FOLLOWS:

COLUMN 1-2	INTERSECTION NUMBER
COLUMN 3	APPROACH DIRECTION
COLUMN 4-5	TOTAL SIGNS
COLUMN 6-7	TOTAL SIGNS--DIRECTLY AHEAD
COLUMN 8-9	TOTAL SIGNS--200 FT FROM INTERSECTION
COLUMN 10-11	TOTAL SIGNS--50 FT FROM INTERSECTION
COLUMN 12-13	TOTAL RED SIGNS
COLUMN 14-15	TOTAL RED SIGNS--DIRECTLY AHEAD
COLUMN 16-17	TOTAL RED SIGNS--200 FT FROM INTERSECTION
COLUMN 18-19	TOTAL RED SIGNS--50 FT FROM INTERSECTION
COLUMN 20-21	TOTAL NON-RED SIGNS
COLUMN 22-23	TOTAL NON-RED SIGNS--DIRECTLY AHEAD
COLUMN 24-25	TOTAL NON-RED SIGNS--200 FT FROM INTERSECTION
COLUMN 26-27	TOTAL NON-RED SIGNS--50 FT FROM INTERSECTION
COLUMN 28-29	PERCENT RED SIGNS
COLUMN 30-31	PERCENT RED SIGNS--DIRECTLY AHEAD
COLUMN 32-33	PERCENT RED SIGNS--200 FT FROM INTERSECTION
COLUMN 34-35	PERCENT RED SIGNS--50 FT FROM INTERSECTION
COLUMN 36-37	TOTAL PUBLIC SIGNS
COLUMN 38-39	TOTAL PUBLIC SIGNS--DIRECTLY AHEAD
COLUMN 40-41	TOTAL PUBLIC SIGNS--200 FT FROM INTERSECTION
COLUMN 42-43	TOTAL PUBLIC SIGNS--50 FT FROM INTERSECTION
COLUMN 44-45	TOTAL PRIVATE SIGNS
COLUMN 46-47	TOTAL PRIVATE SIGNS--DIRECTLY AHEAD
COLUMN 48-49	TOTAL PRIVATE SIGNS--200 FT FROM INTERSECTION
COLUMN 50-51	TOTAL PRIVATE SIGNS--50 FT FROM INTERSECTION
COLUMN 52-53	TOTAL LARGE SIGNS
COLUMN 54-55	TOTAL LARGE SIGNS--DIRECTLY AHEAD
COLUMN 56-57	TOTAL LARGE SIGNS--200 FT FROM INTERSECTION
COLUMN 58-59	TOTAL LARGE SIGNS--50 FT FROM INTERSECTION
COLUMN 60-61	TOTAL SMALL SIGNS
COLUMN 62-63	TOTAL SMALL SIGNS--DIRECTLY AHEAD
COLUMN 64-65	TOTAL SMALL SIGNS--200 FT FROM INTERSECTION
COLUMN 66-67	TOTAL SMALL SIGNS--50 FT FROM INTERSECTION
COLUMN 68-69	TOTAL ACCIDENTS
COLUMN 70-71	TOTAL AT FAULT ACCIDENTS
COLUMN 72-73	TOTAL ACCIDENTS--IGNORED SIGNAL
COLUMN 74-75	TOTAL ACCIDENTS--FAILED TO YIELD
COLUMN 76-78	RELATIVE TRAFFIC FREQUENCY
COLUMN 79	TYPE OF SIGNAL DEVICE

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Holahan received the Publisher's Prize in research competition from the Southwestern Psychological Association in 1974.

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