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PROBLEMS IN THE DETECTION AND IDENTIFICATION OF SIGNIFICANT ROADWAY CONDITIONS

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16. Abstract

To respond effectively to significant roadway conditions, drivers must make timely and accurate detections and identifications. Detection and identification are different processes, and neither is necessarily simple or automatic. This paper discusses both processes; it points out problems with each, and suggests means for improvement.

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Introduction

Even under the least taxing of driving conditions, the operator of a motor vehicle is continuously processing information. Actions are taken based on that information, and the consequences of those actions become more information to be processed.

There is no doubt that most of the information necessary for the safe and effective operation of a motor vehicle is acquired visually. Thus the acquisition and processing of visual information is of major importance in safe driving.

Safe and effective operation of a motor vehicle is generally accomplished with little effort. It is largely a matter of routine responses to routine situations, with a great deal of time left over for conversation, daydreaming, etc. Hence, it is not surprising that many persons apparently regard the associated visual information processing as consisting of two simple steps, i.e.:

DETECTION ➧ RESPONSE

The problem with this two-step model is that, technically, "detection" implies nothing more than a conscious awareness that something is present. The something could be anything, ranging from inconsequential to critical in terms of its importance to the driver. Clearly, the driver needs more information than the knowledge that something is present in order to reach an appropriate decision about a response.

The nature of information-processing is more accurately described by a four-step model (Alexander and Lunenfeld, 1975):

DETECTION ➧ IDENTIFICATION ➧ DECISION ➧ RESPONSE

Confusion about the detection-response model appears to be partly semantic. People use the term "detection," but mean "detection-identification." However, detection and identification are different processes. While identification cannot occur without detection, it is entirely possible to detect and fail to identify properly. Obviously, a failure in the identification stage can have consequences just as catastrophic as a failure in the detection stage.

This is not to suggest that identification failures are common. Fortunately, they are relatively rare. In all probability, it is the normal, close, successful coupling of detection and identification which leads many people to think of them as one process.

In this paper we will explore certain problems associated with detection and identification in the context of motor vehicle operation. The intent is to provide a better understanding of how the visual perception system operates and how certain perceptual limitations affect the processes of detection and identification.

Detection

As noted earlier, detection implies conscious awareness that something is present. The key word is "conscious." The "something" must do more than impinge on the retina of the eye; it must penetrate to the higher levels of the central nervous system to create an impression of being there.

After an accident, investigating officers or witnesses will sometimes judge that a condition was "clearly visible," or they will attempt to estimate the distance at which something became visible. On the surface these seem reasonable things to do. As a result, the judgments may carry considerable weight, especially if there is no reason to suspect a bias on the part of the observers. However, for reasons that have nothing to do with variables such as attentiveness or visual acuity, such estimates by informed observers will almost invariably substantially overestimate actual relative visibility or visibility distance. The rest of this section will be devoted to a discussion of three reasons why this is so. We will also talk about what can be done to maximize the likelihood that detection will occur at safe distances.

1. Focus of Attention

In a classic headlighting study, Roper and Howard (1938) asked subjects to evaluate some headlamp beams. Without the knowledge of test participants, a dark, pedestrian-shaped target had been placed in the path of the car. Measures were made of the distance from the target at which the subject's foot released the accelerator. The subjects were then asked to go back and drive up the road again, releasing the accelerator when they could detect the target. The distances measured under the second (alerted) condition averaged about double those measured under the first (unalerted) condition.

Obviously, Roper and Howard were not measuring just detection distance, since their subjects had reached step four of the model discussed earlier, and were in the process of making a response. Thus, one of the differences between the unalerted and alerted conditions was that the identification and decision phases were probably somewhat longer in the former. However, the study was conducted in such a way that the identification and decision phases were probably quite short in both unalerted and alerted conditions, and the differences between them relatively small. If this is true, the major difference in the response distances was attributable to the detection phase, and it is reasonable to ask why an identical object would be detected at a greater distance just because the subject was specifically looking for it.

In the alerted condition, Roper and Howard's subjects had four advantages they did not enjoy in the unalerted condition; i.e., they knew:

1. That an object was ahead of them on the road.
2. The object's lateral position in the lane.
3. The object's approximate longitudinal position.
4. Specifically what the object was.

This is a great deal of information not normally possessed by drivers under real-world conditions. It made it possible for these subjects to focus their attention in a limited area for a limited time. This has implications for points 2 and 3, which will be discussed later. In addition, knowing what to look for made it possible to infer presence from rather subtle cues. However, these cues would generally not be adequate to ensure detection by a person who had no reason to expect anything to be present, let alone a specific object.

A person who makes a judgment concerning the point of detection or general detectability of some situation, knowing a great deal about that situation, is functioning much like the alerted subjects in the Roper and Howard study. The judgment will possibly be based on partial cues and he/she will probably substantially overestimate the actual detection distance.

2. Peripheral and Foveal Vision

The human eye is capable of responding to light stimuli from a very wide area of the forward field. Yet the "quality" of vision, however it might be measured, is not uniform throughout that field. In particular, there is one area, called "foveal" or "central," where vision is best. In the fovea we can best resolve fine detail, detect low-contrast objects, sense motion, and carry out other visual tasks important to safe operation of a vehicle. This holds true except for very low levels of illumination, where the foveal receptors cease to function; however, this does not happen while operating a motor vehicle, as long as its headlamps are on.

The quality of vision falls off very rapidly from the fovea. The problem is that the fovea is only about 1^{o} in diameter, and accounts for less than 1% of the total visual field. While that portion of the forward scene with which a driver would normally be concerned is considerably smaller than the maximum available visual field, it is still large relative to the fovea. As a consequence, the probability that the image of an unexpected situation will fall on the fovea purely by chance is not very high. Thus, detection often occurs in the periphery of the visual field, simply because its area is so much greater. However, if an object or condition is to be detected peripherally, it must be more conspicuous than if it is to be detected foveally. In the context of operating a motor vehicle, "more conspicuous" is generally achieved by getting closer. For example, Roper and Howard's subjects, many or most of whom probably detected the target peripherally in the unalerted condition, had to be closer than in the alerted condition, when detection was probably foveal. Similarly, an observer who seeks to judge conspicuity or the detection distance to some hazard will be basing his/her opinion on foveal inspection, which is probably not relevant to the real-world driving condition of concern.

3. Capacity to Process Visual Information

As noted earlier, the total visual field is quite large. Because it is so large there is typically more than one item of information impinging on the retina at any point in time. Often much more. However, although the eyes are marvelously efficient collectors of information, the perceptual system has a limited capacity to transmit information to conscious levels. Thus, most information present on the retina at a given instant does not reach consciousness.

Researchers who have studied this characteristic of visual perception have postulated the existence of a "peripheral filter." No specific mechanism has been identified, but it is apparent that the perceptual system filters information and, by some automatic means, determines what reaches consciousness. The system can be overridden voluntarily. That is, we can focus our attention on something as a matter of choice. It is also true that, although the system has limited information-processing capability at each instant in time, it can process a great deal of information, given enough time.

Given a finite information-processing capability, there is substantial survival value in having some lower-level mechanism prescreen and forward to higher centers the information that is most important. By and large, the peripheral filter does this job well.

While the mechanism of the peripheral filter is not understood fully, the characteristics of information it is most likely to pass are well known. In general, these characteristics are ones we say make something "conspicuous." That which is different from its surroundings is most apt to capture our attention. Thus, size, brightness, different coloration or reflectivity, and change (flashing or moving) are characteristics that increase the likelihood that something will pass the peripheral filter and reach the conscious level.

Concern about the peripheral filter as a significant limiting factor in the detection of roadway hazards is greater when there are many stimuli competing for the driver's attention. This is often the case. It is also true that the number of competing stimuli vary greatly from time to time, and hazard markings should be based on the worst conditions likely to occur.

To summarize: detection is a necessary first step in the process that culminates in control actions. In this section consideration has been given to some factors that affect whether and when something is detected. Since judgments of detectability are sometimes made under rather artificial conditions, these factors have been discussed from a point of view of the difference real-world conditions make. The factors are:

1. Given information about a situation, "detection" can be based on subtle cues that would not be adequate in the absence of that information.

2. Detection can occur at much lower stimulus levels if the image of the object or condition falls on the fovea. However, since the foveal area is so small, this is less likely to occur under real-world conditions.

3. The ability of the perceptual system to process information is limited. Thus, the presence of the image of some object or condition on the retina of the eye does not guarantee the information will reach conscious levels immediately. Therefore, assessing something as sufficiently conspicuous based on inspection by an informed person is unrealistic and dangerous.

Identification;

Detection having occurred, the next necessary step is identification.

One can distinguish two levels of identification. They are not equally useful to the motorist and one does not automatically follow from the other. The two levels are:

1. What is it? Typically the first level of identification, this may convey sufficient information for reliable decision-making concerning control actions, especially if the object or condition is static (e.g., chuckhole, debris in the road). If the object is moving, or capable of movement, more information is required.

2. What is it doing? A knowledge of what is ahead and what it is doing is generally all the identification required to enable a driver to infer proper control actions. This level of identification sometimes proves particularly difficult to attain, as will be discussed shortly.

It is important to note that a driver doesn't really need all or any of the information mentioned. It is possible to provide signals that indicate the desired control action directly. An example is the large flashing arrow signs used to indicate lane closures in construction zones. These have good attention-getting value and understandability. The reason for the lane closure is not important, but the message is clear: "move over." The approach whereby desired actions are indicated directly is not used as much as it could be.

The identification process can fail for two reasons. The driver may:

1. fail to make an identification, or

2. misidentify the situation.

Perhaps the most frequent instance where a driver cannot make an adequate identification involves signing. All drivers have encountered signs that were too small, poorly placed, or for some other reason did not convey the intended message in time. The result can be confusion, annoyance, and accidents.

In general, if a driver detects something and thinks it might be relevant, he/she will react with some degree of caution. The heightened attention and/or increased observation time that results will improve the chances of an adequate identification. If something is rejected as not relevant when it is relevant, this is a misidentification failure.

Misidentification can result from cues that provide misleading information. Examples are an exit that appears to be a continuation of the main road, or a curve that appears to have a larger radius than it actually has. Such conditions constitute perceptual traps, providing misinformation that can lure drivers into high-risk situations. Unfortunately, accidents that result from these conditions tend to look like and be ascribed to "driver error." Thus, there has been some difficulty in recognizing the problem in general and in identifying specific locations where such accidents have occurred. Some progress has been made recently and more can be expected in the future.

Misidentification can also occur when available identification cues are inadequate. For example, this can arise when there are large differences in the speed of vehicles moving in the same direction, especially at night. The driver of the overtaking vehicle generally detects the lead vehicle without difficulty. He/she identifies the dynamic relationship by means of apparent changes in the width of the lead vehicle, as defined by the taillights. Judgments whether the gap between one's own and a lead car is opening or closing are the same as judging whether the car ahead is growing larger or smaller. Research suggests that people can do this accurately with speed discrepancies of only a few miles an hour at separations of 200-300 feet (e.g., Evans and Rothery, 1972).

A judgment whether the gap is closing at a low or high rate is more difficult, in that two items of information are required: separation distance and rate of change of image size. Available research suggests that people are relatively poor at this judgment (e.g., Mortimer et al., 1974). At 55 mph, for example, they have difficulty determining whether the gap between theirs and a lead car is closing at a normal-range 10 mph or at a much higher rate until the gap has closed to a dangerous extent. Misidentification in this case results from limitations in human perceptual capabilities, which make it difficult at longer distances to distinguish normal from potentially dangerous overtaking situations. To compound the problem, when the driver has made an erroneous identification, he/she will almost certainly come to an inappropriate decision. Having reached the decision stage, identification of the true state of affairs is generally more difficult, due to reduced attention levels and the fact that, in general, more information is required to change one's mind than to arrive at the original decision.

These kinds of identification errors can be reduced. It requires, first, an understanding of the limitations of the perceptual system; second, a cataloging of the traffic conditions which pose potential problems as a consequence of those limitations; and, third, the development of special signals to aid the identification process where possible.

Perhaps the most important requirement for reducing accidents resulting from problems in identification is to convince people that it is a problem. The DETECTION ➧ RESPONSE model seems firmly imbedded in the public mind. It manifests itself in statements like "if you can see it, there is no excuse for hitting it." It is very difficult to educate the general public, but much could be accomplished if appropriate officials could be made aware of the problem.

A great deal is known about the strengths and limitations of the perceptual system. For example, perceptual research suggests that drivers will have difficulty identifying certain dynamic relationships. In particular, there will be problems estimating the distance and speed of other vehicles. This translates to problems in judging gaps for passing, merging, or crossing maneuvers. Most of these actions are carried out successfully because we have learned, given certain assumptions, what a minimum safe relationship looks like. The system breaks down and accidents occur when the assumptions are violated. For example, if the approaching vehicle is going at a much higher speed than assumed, or if it looks smaller, thus farther away, a dangerous error can result.

For cases where limitations of the perceptual system make identification somewhat difficult, it is important to provide assistance insofar as practical. Some work has been done in this connection. Special markers have been developed for slow-moving vehicles, emergency flashers are standard on all highway vehicles, and commercial vehicles are required to carry and place flares, lights, or markers when stopped on or near the road. Particular attention is being paid to the marking of roadway construction zones.

The techniques mentioned aid identification. In many cases they also improve detection, providing a double benefit. There are other instances where the primary interest has been on improving detection, and the matter of identification has been neglected. An example is emergency and service vehicles. In recognition of the unique needs and problems of emergency and service vehicles, they use special signals. The best of these signals have been developed to the point where they have tremendous attention-getting power, virtually ensuring detection under almost any condition. However, detection having occurred, the approaching motorist is generally left to figure out the situation for him/herself. Interestingly, various public agencies use different colors in beacons designed to aid identification. For example, in Michigan, the police use blue beacons, fire and ambulance vehicles use red, and service vehicles such as snow removal and tow trucks use amber. One problem is that these practices are not uniform. More important, identifying the agency whose vehicle is seen ahead is of little assistance in identifying the situation and deciding on an appropriate response. For example, a police car in hot pursuit uses its signals primarily to say: "Clear the right-of-way." This message is also of importance to ambulances and fire trucks. The police car will often show the same signals while the officer writes a ticket and the vehicle is stopped off the road. This use, as opposed to situation-related use of signals, introduces ambiguity and reduces signal effectiveness.

Since there are a limited number of visual coding dimensions available, it is important that these be used to convey information that will aid the identification-decision process as much as possible. Three messages are especially important:

1. Clear the right-of-way.

2. Slow-moving vehicle.

3. Obstacle on or near the roadway.

It seems important that a uniform situation-related signal system be developed and implemented as soon as possible.

To summarize: identification is an essential step between detection and a decision concerning control activities. It is not necessarily simple and certainly not automatic. But the consequences of a failure in identification can be just as serious as a failure in detection. For some reason, the need for and special problems associated with identification seem not to be adequately recognized. Until they are recognized, identification problems that are relatively simple to solve will persist.

Conclusions

This paper has been concerned with the detection and identification of significant situations while driving. In it we have tried to make these points:

1. Timely detection and accurate identification must occur if effective control action is to result.

2. Detection and identification are different processes. Detection does not ensure proper identification.

3. Neither detection nor identification are simple. There are many reasons why that which is easily detected and identified by one person under a given set of conditions may not be by another person and/or under a different set of conditions.

4. We have sufficient information about human visual information processing presently to be able to deal effectively with many common problems in detection and identification.

By and large the human controller functions very effectively when provided with sufficient and timely information. Failure to provide sufficient and timely information increases the risks of an accident. Unfortunately, the system is such that often the driver and not the inadequate information is blamed for the accident. As a result, drivers are frequently penalized and steps to remedy the basic problem are not taken. It is hoped that a better understanding of the process of visual information processing will aid future design decisions.

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