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EFFECTS OF RISK TAKING AND INATTENTION ON DRIVING

by

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ABSTRACT

The operation of a motor vehicle is, on one hand, a complicated psychomotor task requiring a great deal of diligence and concentration. On the other hand, it is a very well-practiced task which leads to complacency and automated behaviour. As a result, all road users run the risk of being involved in a collision which results from a behavioural error. This error can be the outcome of either risk taking or inattention on the part of one or more road users.

Four separate studies were conducted using varying degrees of enforcement threat. It was posited that if risk-taking was the more significant factor in driving error, then countermeasures that include little threat of enforcement would be less effective than ones with a large amount of threat. Alternatively, if inattention was the major problem, then threat of enforcement would have little influence on behaviour.

The first experiment utilized a series of lines painted on the roadway at diminishing intervals. The lines were highly visual and intended to produce a startle effect with no threat of enforcement. Although there was an initial reduction in speeding, the effect decayed quickly over a three-week period.

A large sign displaying the percentage of drivers not speeding the previous day was used in the second experiment. A low level threat of enforcement was implied and the sign appealed for the driver to conform to the majority. The primary function of the sign was to remind the driver of the speed limit and encourage one to check the speedometer. There was a pronounced speed reduction that endured for several weeks.

Police enforcement was used in the third experiment as a means of reducing the number of drivers that infracted traffic control devices. Traffic lights were used in two instances and a no right turn sign in a third. The results demonstrated that enforcement was useful in controlling driver behaviour but that the effects were short-lived and highly variable.

The last experiment was designed to evaluate driver behaviour at yellow traffic lights, not to influence it. By establishing the distance at which drivers would voluntarily stop at the light, a level of driver attitude about yellow lights was established. This could then be used as a dependent variable in other studies on traffic light behaviour. The results of the study showed good potential for using this approach in future experiments.

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D E D I C A T I O N

To my wife Barbara and
new born daughter Nicole.

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CHAPTER 1

INTRODUCTION

WHY IS DRIVING A CONCERN ?

The goal of a highway transportation system is the development and maintenance of a network capable of moving all road users from one point to another, quickly and safely. Unfortunately, since our present system is less than perfect, there are frequently delays, detours, and traffic collisions. These events then lead to lost time, frustration, stress, damage to property, injury, and sometimes death. There is considerable evidence that these failures are the result of behavioural errors. At the very least they represent a breakdown in an ergonomic system comprised of human road users, motor vehicles, and the transportation network. It would seem that this system is another example of future shock, in that sociological and psychological adaptation has not kept pace with technological advances. As such, it is an area for psychological inquiry.

The extent and cost of the traffic safety problem is considerable. In 1985, Calgary traffic collisions claimed 48 lives and caused 2,694 persons to receive a variety of injuries ranging from minor to life threatening. A breakdown of these costs over the past five years is shown in Table 1.

Table 1

Frequency of collisions and estimates of cost in the City of Calgary during the years 1981-1985

	Fatals	Injury Accidents	Property Damage	Total Cost *
1981	53	3,351	30,761	$153,338,500
1982	56	4,470	29,208	170,993,000
1983	45	2,921	22,613	122,550,500
1984	39	2,864	23,361	120,777,500
1985	48	2,694	26,378	132,257,000

* Total cost based on the following figures (1984 dollars) derived from Transport Canada figures and estimates made by police officers in attendance at crash scenes.

Property damage collision	- $ 2,500	total for all parties
Injuries collision	-$ 5,000	property damage
	-$ 15,000	for injuries
Fatality collision	-$ 9,000	property damage
	$250,000	for the deceased

It should be noted that these costs are shared communally through insurance rates, taxes, and medicare payments. They do not reflect the millions of dollars spent for police and emergency medical services, criminal and civil court costs, or public inconvenience through traffic tie-ups. They also can not account for the psychological and social losses, both for the individuals directly involved in traffic collisions and the many other individuals somehow related to them (Hart and Linklater, 1981). Traffic safety is a pressing societal concern because every collision that is prevented or reduced in severity is a net saving to the community. A financial example is the $2 million saved by the province of Saskatchewan in its first year of mandatory seatbelt legislation (Shiels, 1978).

Problem definition can frequently be the first stumbling block in determining a resolution. If traffic safety is viewed as a behavioural problem, then resources will be directed toward correcting the road user. If the problem is considered to be environmental, then emphasis will be given to the road system. To date both definitions have had support with the assumption that they were unrelated. Vehicles and roads are designed and constructed to the best engineering specifications and then the road user is expected to use them. There has been recent and growing support for a more ergonomic approach, however. All three will be considered in some detail later.

This thesis will investigate the impact that these different definitions have had on the traffic safety problem. It will also examine various countermeasures that are being used to combat it. The primary focus will be on the behavioural aspect of traffic problems, rather than on specific engineering, mechanical or environmental approaches. It is posited that there is no single traffic safety problem, but rather, a collection of behavioural problems that are interrelated to varying degrees. Each individual problem may or may not require an individual treatment. It is also posited that these behaviours result either from a deliberate risk-taking action or through momentary inattention on the part of one or more road users. It is further posited that inattention accounts for a much larger portion of collisions and infractions than is generally recognized.

Several theorectical positions will be discussed, particularly, Wilde's theory of risk homeostasis. There is not, as yet, an accepted theory that adequately explains the relationship of behaviour with the incidence of collisions. This lack is a major stumbling block in the development and evaluation of effective countermeasures. Several current countermeasures are examined and discussed, specifically those that can be used by the police. Particular focus is given to the police, as this agency is potentially a very influential force in traffic safety, with vast resources for research and education that are not presently being fully utilized.

HUMAN ERROR

At present most agencies have defined the traffic safety problem as behavioural and attribute approximately 80-90% of all collisions to the human road user (Shinar, 1978, pg 112; Treat, Tumbas, McDonald, Shinar, Hume, Mayer, Stansifer, & Castellan, 1977). Various investigations of collision data reveal that most crashes occur due to some error in information-processing and/or a behaviour that "an otherwise alert, reasonably skilled, and defensive driver would not have made" (Shinar, 1978, p.112). This also includes behaviours that could have prevented the collision's occurrence or reduced its consequences. Treat defined these behaviours as "human acts and failures to act in the minutes immediately preceding an accident, which increase the risk of collision beyond that which would have existed for a conscious driver driving to a high but reasonable standard of good defensive driving practice" (Treat et al., 1977, p.201).

Although behaviour is a major contributor to the traffic safety problem, the term 'human error' is too vague to be cited as its cause, since the term involves hundreds of individual behaviours. Yet to deal with each behaviour as a separate event would be overly specific and not very useful. A means of obtaining useful data about collision-causing behaviour is a classification system with mutually exclusive categories. Treat et.al. (1977) attempted such a taxomony in the following order of collision involvement.

Improper lookout: delayed recognition due to failure to perform an adequate visual search in a situation that requires a distinct visual surveillance (e.g., in intersections and pulling out of a parking space).

Excessive speed: speed that is excessive relative to the traffic, roadway, and ambient conditions - regardless of the legal speed limit.

Inattention: delayed recognition due to preoccupation with irrelevant thoughts or wandering of the mind.

Improper evasive action: failing to take an emergency action that is apparent and within the capabilities of an adequately trained and alert driver (e.g.locking the brakes and as a result losing control of the car in a situation where steering could have prevented the accident).

Distraction (internal/external): delayed recognition due to an attentional shift to an event, activity, object, or person within/outside the vehicle.

Improper driving technique: engaging in an improper control of vehicle path or speed, in an habitual maneuver (e.g., cresting hills while driving in the center of the road).

Inadequate defensive driving technique: a behaviour that increases the risk of a collision if another driver performs contrary to expectations (e.g., crossing a one-way street without checking for cross traffic in both directions).

False assumption: taking action on the basis of an assumption that is not valid- even if it based on the traffic system rules (e.g., pulling in front of a driver who is signalling a turn but does not in fact turn).

Improper maneuver: willfully choosing a vehicle path that is wrong, since it increases the chance of a collision (e.g. turning from the wrong lane, driving the wrong way in a one-way street).

Overcompensation: improper reactions to emergency situations that cause loss of control, such as overbraking or oversteering (e.g., oversteering back into the highway after going off into the road shoulder).

Critical nonperformance: driver blacks out or falls asleep.

Nonaccident: the collision is intentional (e.g., suicide attempt).

Treat et al. also identified three areas of impairment which "adversely affect the ability of the driver to perform the information processing functions necessary for safe performance of the driving task" (1977, p.212) which were subdivided into 14 specific categories.

1. Physiological - alcohol, other drugs, fatigue, chronic illness, physical handicap, reduced vision.

2. Mental/emotional - emotional upset, pressure from other drivers, in-hurry, mental deficiency.

3. Experience/exposure - driver inexperience, vehicle unfamiliarity, road area unfamiliarity, road area over-familiarity

The above classification system appears to be exhaustive in citing all possible human actions, although there could be overlap in several categories and is therefore not mutually exclusive. It would not be unusual to have more than one human cause contribute to a collision. It would also be very difficult to determine which classification to use if the persons involved were unwilling or unable to cooperate. Persons engaged in classifiying collisions would have to be well trained in using this system and prepared for ambiguities. Ideally this coding should also be done at the scene of the collision, as decisions based solely on reports can seriously impair the accuracy of the evaluation. The biggest drawback to this system is its assumption of behavioural fault, since it would be possible to find almost every person involved in a collision guilty of something on this list. Despite its limitations, however, this is a very well designed classification system for human behaviour and if widely used could yield excellent results. Unfortunately, there is no single format used consistently to report traffic collisions. Each area generally develops its own version. The Calgary Police Service for example uses a 16-point driver action and 6-point driver condition scale to identify human primary and secondary reasons for the collision which is slightly different from others used in the same province.

Driver Action -

1. Driving properly
2. Backed unsafely
3. Followed too closely
4. Improper turn
5. Unsafe speed
6. Left turn across path
7. Left of center
8. Entered lane when unsafe
9. Improper passing
10. Ran off road
11. Failed to yield right of way
12. Pedestrian error/violation
13. Failed to observe traffic control device
14. Failed to signal
15. Other
16. Unknown

Driver Condition -

1. Apparently normal
2. Had been drinking
3. Ability impaired/alcohol
4. Medical/physical defect
5. Other
6. Unknown

This is obviously not as comprehensive as the Treat et al. taxomony and focuses more on the direct action taken by the road user rather than on what was intended or the reasons behind the action. This has given rise to criticisms that police reporting has a behavioural bias. This criticism is likely justified, since police investigators are trained to detect and apprehend violators of the law, causing them to look for a driver error so that a charge can be laid. They are not as familiar with road and vehicle engineering and therefore less likely to consider these areas (Shinar, Treat, McDonald, 1983). The major criticism concerning police reports is inaccuracy and incompleteness. During 1985, there have been 28,465 collisions in Calgary and 25.3% have been coded as other, unknown, or the cause not recorded by the police officer.

POLICE RESPONSE

Traditionally, the police response to traffic collisions is behavioural, consisting of an investigation of the actual event and traffic law enforcement. Proper investigations report the physical circumstances of the collision with an attempt to ascertain its cause. This is generally the sole source of collision information available to any prevention program. Unfortunately, the quality control on these investigations is not stringent, sometimes bringing into question the validity of police-based information (Booth, 1980; Shinar, Treat, & McDonald, 1983).

The other police response to traffic safety is traffic enforcement, whether a collision has occurred or not. In 1974 the Organization for Economic Co-operation and Development defined traffic law enforcement as "the area of activity aimed at controlling road user behaviour by preventive, persuasive, and punitive methods in order to effect the safe and efficient movement of traffic" (Armour, 1984, p.1).

According to this definition, traffic laws exist only to improve the safety and efficiency of traffic flow. Traffic enforcement exists only to increase compliance to those traffic laws. The definition assumes that road user behaviour causes collisions and that controlling it will have the effect of 'safe and efficient movement of traffic'.

Over 150,000 summonses a year are issued in Calgary for traffic law infractions. The majority of these offences do not arise from collisions or near-misses. The summons is issued because the offence occurred regardless of the circumstances of the offence. The logic behind this type of enforcement is that a person who violates a traffic law in a low risk situation may also violate the same law at some other time when the risk is greater. By punishing the person now, the possibility of a later violation is reduced. There is a firmly entrenched belief that with enough enforcement any safety problem can be eliminated. It is also believed that infraction rates can be reduced significantly by raising penalties such that no one could afford to infract a traffic law. Yet there are no indications that Calgary's high enforcement rate has had a positive effect on the collision rate. The idea that the threat of serious punishment will result in unfailing vigilance and compliance reflects a behavioural bias as to the cause of traffic infractions and a belief that risk taking can be removed through deterrence.

An enforcement program may use both marked and unmarked vehicles, in either static or line patrols, to achieve its end of deterring road users from committing traffic infractions. The deterrent effect is specific to an individual when he/she is stopped and summonsed. There is also a general effect of deterrence on others who witness this enforcement activity or otherwise have knowledge of its existence. This knowledge is a critical factor for deterrence, since it is not so much what police do, but rather how it is perceived by road users (Shinar, 1978). Shinar further states that deterrence is determined by the level of threat presented by visible enforcement units and their density (number of enforcement units per kilometer of driver travel).

Although marked vehicles contribute a high degree of visible police presence, there are generally very few of them on the street at any given time. This could have a deleterious effect on general deterrence levels if the public perceives their risk of apprehension as being quite low. Unmarked police vehicles may offset this problem somewhat by encouraging a belief that there are more police vehicles present but that they are invisible to casual observation. Some researchers believe that while unmarked vehicles increase the objective risk of apprehension they decrease the perceived risk since they are not visible or identifiable as enforcement units. "The idea that the motoring public will respond to any vehicle as if it were an enforcement vehicle is unrealistic" (Shinar, 1978, p.396).

A line patrol consists of police vehicles circulating in the general traffic and observing whatever offences might occur. Although this covers more ground, only vehicles in close proximity to the police car will be monitored. This type of patrol reinforces the idea that the police could be anywhere and includes the general movement of police vehicles responding to calls. Booth (1980, pp. 139-144) showed that this can be particularly useful in establishing the omnipresent image of police unmarked vehicles.

A police vehicle sitting at a specific location monitoring the traffic that flows past is a static patrol. Although this mode limits the police car to a specific location, exposure is increased, since more people drive past and see the police vehicle. This is also more consistent with the philosophy of enforcing specific infractions at specific locations (selective enforcement). Joscelyn, Bryan and Goldenbaum (1971) showed that stationary marked police vehicles were more effective in slowing traffic down compared to other techniques such as roving marked patrol cars and unmarked police vehicles. Static patrols are also easier on the vehicles, less expensive to run, easier to monitor, and generally result in more summonses per manhour.

Further studies on static patrols have questioned whether they are effective when they have a motorist stopped. Joscelyn et al. (1971) found this to be the most threatening position, in that there was a marked reduction in speed immediately, although the effect was not as long-lasting as when the police vehicle was alone. Booth (1980) found this situation to be the least effective in slowing down traffic. Since the police officer was already occupied, the drivers may feel safe from apprehension. This feeling of safety has been shown in most studies, in that the effects of the patrol car on speed were greater for traffic travelling the same direction as the patrol car than for traffic going the opposite direction.

How far the impact continues downstream is known as the halo effect, which Dart and Hunter (1976) defined as the effect enforcement has on traffic behaviour beyond the point where the enforcement (or threat of enforcement) is actually applied. The halo may also extend upstream from the location due to opposing traffic flashing their headlights to warn others about the radar. This halo varies widely from one location to another, and from one time to another, from less than a kilometer downstream to up to 10 kilometers. It is not always clear why or how this halo effect fluctuates. A specific location can have a considerable variance in halo length in just a few days. A police presence serves to increase attention to speed so it may be effective in reducing speed problems due to inattention, but only when the car is there. For those drivers who deliberately speed the effectiveness of the patrol will be in direct relationship to the degree it increases their perception of risk. For this reason the halo can be extended considerably when there is a second static patrol some distance past the first. The halo of the second patrol will generally be double or triple that of the first (Joscelyn et al. 1971).

The residual impact, referred to as the time halo by Hauer, Ahlin, Bowser (1980), is another measure of the effectiveness of enforcement. This is the length of time after enforcement that road users will remain cautious at a specific location. A horizontal residual impact is measured at the same time of day across days. A vertical impact is measured on the same day but across time of day. A static radar car may, for example, set up between 1000-1100 on Monday, Wednesday, and Friday during a given week. If successful in affecting speeding behaviour, a horizontal residual might be expected on Tuesday, Thursday, and perhaps on the weekdays of the following week between 1000 and 1100. A vertical impact might occur on Monday (after 1100), and on Wednesday, or Friday of that week but either before 1000 or after 1100. A combined vertical-horizontal impact would be at different times, on different days.

Generally a horizontal impact is the most common, providing that traffic is relatively homogeneous (the same road users travelling the same route at roughly the same time each day). If the same vehicles commonly travel that route but at different times of the day, then the chances of a vertical impact increase. The effect may be diffused however, because of other vehicles that have not been exposed to the static radar car. The degree and type of impact is dependent upon the number of people exposed to the enforcement procedure and the frequency of the exposure.

Horizontal residual effects may last up to several weeks in the absence of enforcement, but only when it has been sustained and consistent (Booth, 1980, pp 325-340; Brackett and Beecher, 1980; Brackett and Edwards, 1977). The main factor for long-term residual effects is the initial duration of the enforcement and the probability of its return. By varying time and placement of the radar site on a relatively homogeneous driving population, the residual impact of a single radar car can be quite extensive.

Other studies have indicated that even though residual effects can be found horizontally in time, there is almost no vertical residual effect, no matter how durable the enforcement (Cooper, 1975). To be effective drivers must have personal experience with the enforcement. This experience could be vicarious through stories or media exposure, and thus many communities favor media safety campaigns as a means of modifying behaviour. Shinar (1978) supports the use of media, indicating that well publicized enforcement efforts can greatly increase the perceived risk of enforcement. These strategies assume, however, that the problem is behavioural with individuals engaged in risk taking. It would be useful, therefore, to examine risk taking in more detail.

CHAPTER II

RISK TAKING AND INATTENTION

RISK TAKING

The belief in enforcement as a means of influencing driver behaviour stems from the knowledge of punishment as a learning tool. There has been a great deal of research, however, that now questions punishment as a good motivator (Hilgard, Atkinson & Atkinson, 1979, p.207; Walters & Grusec, 1977). Basically, these motivation and learning theories state that people will almost always work toward their own best interest and will therefore do those things that accomplish their goals and meet their needs. If a behaviour is successful in satisfying a need, then the behaviour is reinforced.

Positive reinforcement occurs when the behaviour produces a desirable benefit, such as the exhilaration of high speed driving. Negative reinforcement occurs when the behaviour removes something unpleasant, such as the penalty of being late for work. In both cases the behaviour, driving fast, is likely to recur. Punishment, on the other hand, is an attempt to reduce the recurrence of a behaviour by associating it with an unpleasant consequence, such as a speeding summons or the possibility of a traffic collision.

In evaluating the impact of reinforcement and punishment on driving behaviour it is necessary to determine the perceived utility that a person will receive from the behaviour and the perceived cost. Most utility based theories assume that the individual can measure these variables and derive a net benefit from them. Bentham (1792) put forward the concept that man had two sovereign masters; pain and pleasure and that the principle of utility approved or disapproved of every action that an individual took.

Utility is defined by Bentham and other writers as the property of any object or event whereby it tends to produce benefit, advantage, pleasure, good or happiness, or to prevent mischief, pain, evil or unhappiness to the party whose interest is under consideration, be it an individual or a community (Feinberg, 1976). Bentham proposed that the given utility or disutility of something could be measured directly in relation to its intensity, duration, certainty (or lack of), and its propinquity (or remoteness). Two further measures are included if one is evaluating the object or event producing the utility, its fecundity (the chance that one sensation will be followed by a sensation of the same kind, pleasure followed by pleasure) and its purity (the chance of the sensation not being followed by sensations of the opposite kind). These measurements demonstrate the complexity that any given behaviour can have as it can vary along any of these dimensions. Table 2 compares the two main sources of driving disutility along these measures.

TABLE 2

The effect of a traffic summons or a traffic collision on the various aspects of disutility

	TRAFFIC SUMMONS	COLLISION
INTENSITY	Low -usually under $100	Can be very expensive, time-consuming, and may involve considerable pain
DURATION	A few minutes initially with points lasting two years. Court is a few hours if req'd	An hour for the initial report, 1-2 hours for the insurance follow-up Possibly months of med. treatment and follow-up.
CERTAINTY	Relatively rare .01 -.0001 probability	Approx 1/6 the probability of a summons. **
PROPINQUITY	This would refer to general deterrence eg, the person in front of you getting a summons for what you are doing.	same as a summons but usually more intense.
FECUNDITY	May have to follow up the summons with a court appearance.	Considerable follow up with insurance, body shop, and court.
PURITY	Each event is unique and a positive event is unlikely to follow a summons unless there is a change in driving behaviour.	The insurance may pay sufficiently for a better car or some other benefit.

* (Slovic et.al. 1977)
** (Calgary Police Service Annual Statistical Report)

Essentially, utility theory describes a means of measuring risk taking behaviour, with risk being the price willing to be paid to derive a net benefit. The concept of risk is difficult to apply, however, because its interpretation varies. Vlek and Stallen (1980) offer seven possible definitions which vary primarily on the relationship between the utility of behaviour and the subjective probability that a given result will occur. The following definition will be used for this paper (paraphrased from Bentham).

1. An author of an action incurs a risk whenever a negative consequence (disutility) can result from an action or inaction that is designed to produce a positive consequence (utility).

2. This entails that the author realizes that a given action or inaction may have two or more consequences providing various degrees of utility and disutility and that an objective probability exists for any possible consequence to occur.

3. In deciding a course of action the author may determine a subjective probability of any given consequence occurring which may or may not equal the objective probability of such occurrence. This may or may not be independent of the anticipated utility or disutility resulting from the decision.

For example, a driver may speed to achieve a specific utility, exhilaration, or avoid a specific disutility, being late. The risk of speeding is a traffic summons or a traffic collision. The driver must be aware that these are possible consequences of speeding and have made a subjective evaluation of their probability compared to the subjective worth of the behaviour in order for him/her to be risk taking. This definition of risk presumes that the risk taker is deliberately engaging in a behaviour after having evaluated its subjective benefits and costs and concluding that the behaviour yields a net benefit. This philosophy is the basis for Wilde's theory of risk homeostasis discussed later.

In order to calculate this benefit, an individual will have to be fairly adept at determining the probabilities of uncertain events occurring. Recent research in decision making has revealed that many, otherwise intelligent, people systematically violate rational decision making principles when attempting to cope with probabilistic tasks, particularly when the event has a low probability but a high consequence (Slovic & Fischoff, 1980). Even the way in which risk information is presented will have a major effect on risk assessment. Saying that one's annual chances of death has shifted from 1 in 10,000 to 1.3 in 10,000 will have a much less dramatic effect than saying that there has been a 30% increase in annual mortality risk (Slovic & Fischoff, 1980) Rather than calculate specific probabilities people will frequently favor the use of various judgmental heuristics which reduce difficult tasks to simpler guides but which can lead to large and persistent biases (Slovic & Fischhoff, 1980; Tversky & Kahneman, 1973).

One common heuristic is "availability", where an event is viewed as likely or frequent if it is easy to imagine or recall instances of it. "Generally instances of frequent events are more easily recalled than instances of infrequent events, and likely occurrences are easier to imagine than unlikely ones" (Tversky & Kahneman, 1973 p.210). This heuristic is also affected by factors such as recency, vividness, and emotional salience. Since traffic collisions and enforcement statistics are commonly reported in the press, often in colorful detail, there is a tendency to overestimate the frequency of serious injury or death from traffic occurrences (Slovic, Lichtenstein, Fischhoff, Layman & Combs, 1976). There is also an overestimation of the probability of apprehension and punishment from traffic infractions.

Denial is also a factor which effects probabilistic reasoning. Many people have difficulty facing life as a gamble and have a strong desire for certainty (Lichtenstein & Slovic, 1973). Low probability events are treated as if they were completely impossible (Kunreuther, Ginsberg, Miller, Sagi, Slovic, Borkan, & Katz, 1980). This is demonstrated by interviews of flood victims in the U.S. who flatly denied that floods would ever recur in their area and quickly proceeded to rebuild their homes, even though nothing had been done to prevent such a recurrence (Slovic & Fischhoff, 1980).

Overconfidence and complacency are also factors that effect probabilistic reasoning. Since no negative consequences have occurred to the road user up to now, why should this particular time be different? Impaired drivers are quite adept at using this justification for driving. They reason that, "I've made it home safely before when I was much drunker, so nothing will happen this time either!". The very fact that the event is of low probability contributes to a feeling that it is a non-issue. When possible outcomes are couched in terms of probability distributions they are seen as wishy-washy, and often trigger anxiety and uncertainty in people who have to make a definitive response.

Another bias called 'the wisdom of hindsight' will also influence subjective evaluations of risk (Slovic & Fischhoff, 1980). The main result of studies in hindsight and second-guessing is that people exaggerate what could have been anticipated with foresight. Not only is the outcome of the behaviour considered inevitable under the circumstances, but also it should have appeared relatively inevitable to any reasonable person prior to its happening. People generally believe that others should be able to anticipate events much better than is actually the case.

It is certain that the process of risk assessment in traffic situations is at best a haphazard art. Not only is there considerable influence from various decision making processes mentioned above, but there is also a lack of reliable data available to most road users with which to make accurate predictions. With every road user making subjective evaluations regarding costs and benefits, developing a reliable theory of risk taking behaviour based on the ability of road users to make these decisions would be an arduous and ambitious task. One of the more widely debated examples is

Wilde's Theory of Risk Homeostasis which has done much to promote interest in this area.

WILDE'S THEORY OF RISK HOMEOSTASIS

This theory states that at any given moment a road user will perceive a certain amount of risk. This perceived risk is compared with the amount of risk that the person is willing to accept at that moment. If the amount of perceived risk is greater than the amount tolerated, the road user attempts to use a greater amount of caution. If the perceived risk is less than the tolerated risk, the road user will be inclined to reduce his/her level of caution commensurately. The degree to which the perceived risk agrees with the actual risk will depend on the person's perceptual and probabilistic reasoning skills.

Wilde compares this process to the thermostatic control of room temperature in a house. When the temperature drops below a specified point, the thermostat signals the furnace to turn on until the temperature reaches the specified level at which time the thermostat signals the furnace to shut off. The house occupant sets the thermostat to a subjectively perceived comfortable temperature. Likewise, a driver sets a subjective risk acceptance level to maximize net utility and will drive accordingly. For example, a driver may feel comfortable driving at 60 kmh in a posted 50 kmh zone given his perception of risk and his level of risk acceptance. As the road and traffic conditions change, vehicle speed will be adjusted down or up to maintain that risk level (heavy cross traffic and a narrowing of the road will likely result in a speed reduction, whereas a wider, lightly travelled roadway might result in a higher speed). Wilde views this process as a closed loop with only the road user's target level of risk outside the loop. "It is, therefore, suggested that the only variable that ultimately controls the system's output (accident frequency/severity) is the target level of accident risk" (Wilde, 1982 p.212).

Wilde concludes from this that if each road user's target level of risk, and the adjustments he/she makes to maintain it, were totalled across all road users in a specific area (yielding some constant, k), over a given time span, the result will be the frequency and severity of traffic collisions for the same area and time. From this Wilde derives the formula (A/T=k) where A is the sum total of all collisions multiplied by their degree of severity and T is the total amount of time spent in traffic by the aggregate population in that area (Wilde, 1982). The value T can be expressed as the average amount of time (t) per capita (C) spent in traffic (T=t*C and A/t*C=k). Wilde then rewrites the term t as the length of distance covered (km) and the average speed (s) in covering that length (t=km/s) thus A*s/km*C=k. Since average speed s equals km/h, he finishes with the equation (A*km/C*h*km = k).

According to Wilde's theory any safety program that does not adjust the driver's desire for risk will have no long-lasting effect on collision rates averaged over time. At best it will produce a short-term fluctuation in the collision rate, which will then return to its base rate or pre-exiting trend. Without a change in the target level of risk the collision frequency per hour of exposure will remain constant.

Wilde predicts that the introduction of a new safety feature or legislation will decrease an individual's subjective evaluation of risk and subsequently increase the target level. This would also increase the likelihood of risky behaviour. "As the frequency of poliomyelitis goes down, fewer people will participate in voluntary vaccination programs and the changes of resurgence of polio incidence would increase. As medically supervised abortions become more available, more unplanned pregnancies will occur"(Wilde, 1982, pp 222-223). Wilde cites various studies on seatbelt installation and mandatory use law (Adams, 1981; Peltzman, 1975) where these programs failed to decrease collision mortality rates. Adams concluded that this legislation was counterproductive to safety because "protecting car occupants from the consequences of bad driving encourages bad driving" (1981, p.6). Adams also felt that the same mechanism may apply to mandatory helmet laws for motorcycle riders. This seems to be a Darwinian approach to traffic safety, in that undesirable drivers will eventually die off leaving only good drivers, if we stop protecting them.

Many writers disagree with this idea and have found considerable benefits derived from seatbelt legislation (Deuth, Sameth & Akinyeni, 1980; Evans, 1985; Evans, Wasielewski & von Buseck, 1982; Lund, O'Neill, Ashton & Zador, 1984; MacKay, 1984). One major problem with using fatality information for these types of comparisons is the large amount of variability from one year to another for no apparent reason. Also most traffic fatalities occur on highways, at high speeds, with seatbelt effectiveness diminishing at speeds in excess of 60 km/h (Green, 1982). Few seatbelt studies discriminate between rural and urban collisions in their analyses or take into account pre-impact speeds. Adams' comment on helmet law was not supported when 26 U.S. states repealed mandatory wearing laws in the late 1970's (Chenier & Evans, 1984). These states collectively experienced a 28% increase in motorcycle fatalities compared to the states which did not change their laws. Many of these states have subsequently reintroduced the helmet law.

Wilde believes that the road users' estimation of these safety devices and laws will have a major effect on the resulting collision rate. If the benefits are overestimated then there could be an increase in collisions as the target risk acceptable to drivers increases beyond what it should be. Apparently there have been several post hoc studies done on the effect of installing traffic control lights on collisions rates which indicate that, although right-angle collisions decrease at these intersections, there is an increase in rear-end, left-turn, and side-swipe collisions (Box, 1970; King & Goldblatt, 1975; Roer, 1968; Vey, 1933). Although driver behaviour was changed by the installation of the lights, total collisions were not (assumedly because risk acceptance wasn't altered by the traffic control lights).

If the safety benefits are underestimated, then risk acceptance will fall and so will collisions. As evidence Wilde cites the change-over from left-hand to right-hand driving in Sweden and Iceland. In both countries fatal and injury collision rates dropped substantially immediately after the change-over. Sweden returned to pre-existing trends, however, after approximately two years, and Iceland after approximately 2.5 months (Näätanen & Summala, 1976). He credits that difference in time interval to the difference in population, with Sweden having roughly 40 times the number of inhabitants.

Wilde's conclusion is that preventive programs must "stimulate the desire to avoid accidents" (Wilde, 1982, p.10) and not simply be directed at particular behaviours like speeding, drinking and driving, and seat-belt use. He states that there are four ways in which the target level of risk may be lowered:

1) Decrease the expected benefit of risky behaviour
2) Decrease the expected cost of cautious behaviour
3) Increase the expected benefit of cautious behaviour
4) Increase the expected cost of risky behaviour

Although Wilde cites several examples of each tactic, he adds that many will not be successful, as they are directed at particular behaviours like speeding, drinking and driving, and seatbelt use, and do not stimulate the desire to avoid collisions. Traffic enforcement (an example of tactic 4) is considered to be a "surrogate risk" because it motivates drivers to avoid a penalty, but does not heighten the desire to be safe. Reducing the frequency of one particular collision cause may simply make room for other causes to become more prominent. Wilde distinguishes between three types of motivational countermeasures:

1. those which discourage driving, while encouraging the use of safer means of transportation;
2. those which discourage specific unsafe driving acts;
3. those which increase the costs of accidents to individuals involved and increase the benefits of not having an accident.

As already mentioned, Wilde feels that type 2 is unlikely to have long term effects. With regard to type 3, he expects that the collision rate will decrease as the gap between the perceived cost of having a collision and the perceived benefits of not having a collision is widened.

Although this theory has done a great deal to promote interest and research in driver motivation and has contributed to basic understanding of the area, there are some unanswered problems that seriously undermine the theory as a "comprehensive conceptual framework of accident occurrence and road-user behaviour" (Wilde 1981 p.8). This is not to say that the theory does not offer some interesting and valid countermeasure proposals which may work in and of themselves. It is questionable, however, whether this theory can justifiably be compared to the physical laws of Ohm, Weber, and Boyle/Gay-Lussac (Wilde, 1982, p.252).

In the first place Wilde has developed a mathematical formula which he claims offers empirical verifiability of his theory (A/T=k or A*km/C*h*km=k). He does not make it clear, however, why this formula supports the theory. The formula seems to state that total collisions are positively correlated with the number of drivers and the amount of time they spend in traffic. If more drivers spend more time on the road then the number of collisions should increase. This logic seems more descriptive than predictive. The theory is held together by using a constant k that supposedly represents the sum of all road-users' target levels of risk, which seems very difficult to validate with any objective data.

Wilde then states that these equations establish a clear distinction and relationship between collision rate per unit distance, per time unit of exposure, and per capita. If speed (s) increases, then A/km*C (or collisions per kilometer per capita) will decrease. This would appear to be a contradiction to the observation that there is a positive correlation between speed and injury severity which Wilde dismisses by saying that an increase in s is associated with divided, controlled access, roadways with higher speed limits and lower collision tolls per kilometer. It is questionable then whether Wilde ever intended this theory to be applicable to real life situations under differing conditions.

By using somewhat vague terms, Wilde also manages to make this formula difficult to test. He defines A, for example, as the sum total of all collisions, each multiplied by its degree of severity but does not indicate how severity will be measured. He does not appear bothered when he redefines A (within 6 paragraphs) by stating that if A/km (now representing fatalities only) decreases over several decades (as roads and vehicles improve) then km/C*h will increase (Wilde, 1982 p.250). He uses the years 1943-1972 as examples in which there was a substantial increase in the number of vehicles, the number of drivers, and the number of kilometers driven in the U.S.. Although fatalities also increased during this time period, the death rate per mile decreased from 11.44 deaths per hundred million miles to 4.43 deaths per hundred million miles (National Safety Council, 1984). This would seem to be inconsistent with the theory's main tenet that collisions per unit time will remain consistent without a change in drivers' target level of risk, unless there was a 258% increase in average travel speeds (11.44/4.3 = 2.58) from 1943-1972.

Evans (1985a) reports two studies (Herman, & Lam, 1975; Horowitz, 1984) which indicate that present day average travel speeds are around 25 mph (40 kmh). These figures are obtained through two surveys measuring the time required for vehicles to cover a specific distance. Travel speeds are much lower than spot speeds because of the effects of traffic congestion and the interactive influences from other road users and traffic control devices. Although there does not seem to be reported data on how average travel speeds have changed since 1943, for Wilde's theory to be accurate the average travel speed in 1943 would have had to be about 10 mph, which is unlikely, since there was far less congestion and fewer traffic lights.

It is not clear why Wilde restricts himself to pre-1972 data. He claims that post-1972 data were excluded because of the possible effects of the energy crisis upon the values of h and k. It seems a questionable practice to exclude data on the grounds that they might not support your theory. Evans (1985a) reports that there was a substantial reduction in traffic fatalities per unit time of driving following the imposition of the 55 M.P.H. speed limit in the U.S. during 1972. Wilde's restriction to pre-1972 data also excludes the impact that improved technology and prevention programs introduced over the last 13 years may have had on driving behaviour and collision rates.

This new technology introduces another problem with Wilde's model. For road users to compensate for a safety measure it is necessary for them to be able to detect the change in risk. How can a road user accurately assess the crashworthiness of a vehicle? McKenna (1985) states that some safety measures are 'psychologically invisible' to most road users. This would include items such as collapsable steering columns, energy-absorbing dashboards, break-away street lights, and forgiving guard rails. It is not likely that a given road user would be able to evaluate or even detect these safety measures in order to compensate for them.

Another concern that the theory does not address satisfactorily is the global consciousness that involves all road users. Wilde notes that a decrease in the fatality rate among drivers is offset by an increased risk of death to pedestrians (Wilde, 1981; Peltzman, 1975). On one hand Wilde is stating that at any given time an individual will compare his target level of risk with the perceived risk around him in order to decide the risk he will accept and on the other hand stating that this homeostatic mechanism operates on a societal level as well. "Each country appears to have the accident rate it accepts in return for the amount and manner of mobility it wants" (Wilde, 1982b, p.225). This would almost necessitate a collective consciousness in which one person's decrease in risk acceptance is balanced by another person's increase in risk acceptance. Wilde put a lot of emphasis on Peltzman's data which have been effectively challenged by several people as being theoretically inappropriate and poorly constructed (Joksch, 1976; Lindgren and Stuart, 1980); Robertson, 1977).

Another problem of the risk homeostasis theory concerns its focus on collisions as the major source of disutility arising from poor driving. Wilde claims that accident frequency/severity is the output of his homeostatic system. Collisions are viewed as the result of a trade-off between the benefit drivers receive from engaging in risky behaviours and the costs associated with taking risks. He also states that the collision rate will decrease only when the gap between the perceived cost of having a collision and the perceived benefits of not having a collision is widened. This assumes that a collision is an event which is controllable by the road user and can be specifically modified by the road user's desire to be safe or the target level of risk.

In reality, a collision is an unplanned by-product of various behaviours and conditions, some of which may be influenced by a given participant in a collision. A specific driver may or may not drive through a red light and a pedestrian may or may not step from the curb directly in front of a vehicle. The result will be a collision or a near miss depending on the amount of attention each is paying to the situation, the speed of the vehicle, the reaction capabilities of both parties, the mechanical condition of the road, and the weather conditions. If a collision does occur, the severity will also depend on many of the same factors as well as the relative health and vitality of the pedestrian, the response time of emergency medical services, and the exact manner of impact.

The difficulty of this preoccupation with collisions and the road users' involvement in them becomes more apparent when the risk homeostasis model is applied to designing prevention programs. Wilde claims, for example, that lower insurance fees for collision-free driving could be used to shape driver behaviour. He also states that drivers could be offered small monetary incentives for collision-free driving. Harano and Hubert (1974) report a 22% reduction in collisions as the result of rewarding drivers for collision-free and violation-free driving through free extensions of their driver's license.

Involvement in a collision is probably the most deleterious event that can occur during a driving career, especially if that collision involves death or serious injury. It is unthinkable that a sane person would deliberately involve himself in such an event or even knowingly run the risk of such an event if he thought a collision was inevitable, unless very highly motivated. It is doubtful that being late for work would suffice as such a motivator. Yet people repeatedly use this as an excuse for speeding behaviour. It would logically follow that these individuals must not associate a specific incidence of speeding behaviour with a high probability of being involved in a collision. In fact, the odds of ány specific trip ending in collision are very low. In 1983, Alberta Transportation reported that the collision rate was 513 per 10,000 licensed drivers, and 415.5 per 100 million vehicle kilometers. The average driver would travel approximately 240,674 kilometers before having one collision.

Wilde does not spend a great deal of time discussing the role of police intervention, which he considers as 'surrogate risk', in his model. This is unfortunate because the subjective risk of receiving a summons is probably much greater than that of being involved in a collision, since it a far more common event. In 1985 there were 28,465 collisions in Calgary but over 150,000 traffic charges were laid. The chances that a given driver would receive a summons was 4.58 times that of a having a collision. A summons is also the direct consequence of a specific unlawful behaviour and is completely within his/her control. As long as the driver is engaged in a violation, such as speeding, there is the risk of detection and penalty. The road user is, therefore, in a better position to evaluate the utility derived and level of risk incurred from a specific controllable behaviour than from a marginally probable event such as a collision.

Although Evans (1985b) devotes an entire paper to refute tne Risk Homeostasis Theory, he does mention that the theory played an important role in helping point out that engineering changes are only one of a number of vital ingredients in traffic safety systems. He also indicates that there is a strong need for the development of theories in this field so that information can be fitted into understandable patterns and judged on the quality of that fit. He therefore offers his own model for discussion called the Human Behaviour Feedback Model (Evans, 1984 a,b). This model states that for every engineering change designed to increase safety there would be an actual change in safety related to the engineering change but not necessarily identical to it. This is expressed in the formula;

Actual safety change = (1+f)*(engineering safety change)

where f is a human behaviour feedback parameter analogous to feedback in electrical systems. If f=0 then the change is non-interactive and the user does not change his behaviour in response to the engineering change. If 0>f>-1 then the actual change is less than the engineering effect, but still in the same direction. If f=-1 then there is no actual change associated to the engineering change, which would be the closest to Wilde's Risk Homoeostasis Theory.

Evans cites several examples for each of these possible occurrences. An advantage of this model is that most available data can be fitted into it. In fact it is really little more than a collection of previous theories (including Risk Homeostasis) joined together to form an all-inclusive continuum. As such it shares the disadvantage of these theories in that it has no predictive ability concerning human behaviour in a given traffic situation or the efficacy of a given countermeasure. At best this model can classify the countermeasure by its result once it has been tried and evaluated. Evans argues that while this is a drawback, it is better than no theory at all (which is little consolation).

As Evans has stated a workable theory is necessary to any field of research in order to organize and direct research activity. Ideally a theory should explain, in quantifiable terms, why a given phenomenon exists so that further research will either support or refute it. To be useful, a theory should also have some predictive ability so that it can be used in evaluating responses to the problem. The goal, after all, is to reduce traffic collisions and their severity in some cost effective manner and still maintain an efficient transportation network.

Although risk taking is an important element in traffic behaviour, it is only one of many aspects of the task. For most people, most of the time, driving (or some other road user role) is simply a means to an end. Quite often, operating a motor vehicle is a disutility in itself; a high initial cost, insurance, maintenance, parking, traffic jams. The same can be said for public transportation or walking.

it must be done, however, because the person obtains utility from working or arriving at some destination at a specific time and this is the means to get there. The majority of road users are quite content to obey most traffic rules, most of the time. Yet these people are also involved in collisions quite frequently. It does not seem possible that a comprehensive traffic behaviour theory can be developed that does not account for inattention and its effect on infraction rates and collisions.

INATTENTION

As mentioned earlier, the above theories are behavioural in nature and assume that road users are fully cognizant of their actions and consequences. Given the nature of the driving task this assumption is unlikely to be true. The operation of a motor vehicle "is a divided attention task, in which many activities must be performed simultaneously" (Testin & Dewar, 1981, p.111). Inexperienced drivers usually have a great deal of difficulty coordinating the wide range of tasks that are required of them and must focus a great amount of concentration and attention on what they are doing. Gradually these demands become much easier with many tasks being performed almost automatically. Along a familiar route most experienced operators can drive quite acceptably with considerable distraction and a minimum of attention. This, however, can lead to a great number of errors being committed through inattention if something unexpected occurs.

Several studies on experience and driving indicate that through experience a driver learns to ignore information that is not important. Since novice drivers lack this ability, they pay inordinate amounts of attention to the task and therefore miss vital information, which may account for the high collision rate among drivers aged 16-19. Experienced drivers look further down the road than do novice drivers using their peripheral vision to maintain road position. Experienced drivers also sample their mirrors more (Mourant and Rockwell, 1972). Experienced drivers see and interpret more signs than novice drivers (Summala and Näätanen, 1974). The importance of successfully dividing attention while driving was demonstrated by Kahneman, Ben-Ishai, and Lotan (1973) and Mihal and Barrett (1976). Both studies found significant correlations between a person's collision record and his/her ability to shift attention rapidly in a divided attention task. Yet inattention is responsible for 10-15% of all collisions when a strict definition is used, and as much as 25-50% when inattention is more broadly defined (Treat et al., 1977; Zaidel, Paarlberg, and Shinar, 1979).

Inattention is defined by Zaidel et al. (1979) as "inappropriate or insufficient attentional behavior relative to the attentional demands of the situation in which a driver is performing" (p.118). Shinar defines it as a "delayed recognition due to preoccupation with irrelevant thoughts or wandering of the mind" (1978, p. 117). The Alberta Highway

Traffic Act (RSA 1980, Section 123) makes it an offence of careless driving to operate a vehicle without due care and attention. From this it can be seen that the degree of attention that a driver or other road user must exercise may vary considerably from one situation to another.

Generally the level of attention will be measured by how quickly the road user can perceive a dangerous situation, allowing time to react. The ability to do this will depend on the physical layout of the area and the ability and attention levels of those involved. At every collision or near collision there is a point where the conflict becomes possible, and it can be seen by those involved, known as the point of possible perception. There is another point when one or more of the people involved become aware of this potential conflict, a point of actual perception, and a point of no return where the conflict is unavoidable by those involved. Providing that reaction to the danger occurs before the point of no return, a conflict can be avoided. The amount of time available for reaction will depend on the distance between the point of actual perception and the point of no return, and the speed at which the participants are approaching. There are occasions where the point of possible perception lies between the point of no return and the crash site. In this case the collision is unavoidable. Obviously as speed increases then the time available for perception and reaction will decrease.

In analyzing the driving task many researchers have focused on the task itself and determined the physical and mental limits within which the operator must function. This has generally involved laboratory and field work under tightly controlled conditions and has examined reaction time, auditory and visual acuity, form resolution, color perception, sensitivity to illumination, decision making, and information processing. From this research, engineers and manufacturers have tried to optimize the driving environment to stay within operator limitations and to maximize the ergonomic design of the vehicle. Shinar defines the road user as a "limited-capacity information processor whose efficiency (and safety) is enhanced or degraded by the highway and vehicle design features, as well as by his or her personality, skills, and impairments (1978, p.ix)." Although a great deal of work has been done on determining the limitations of the information processor, there has not been enough emphasis on the impairments, particularly inattention.

There are several problems with studying inattention. For one, it is difficult to recreate in a controlled environment. Attention is normally determined by an act of perception, which in turn is determined by a reaction of some kind. At a collision scene it is assumed that the point of actual perception is just prior to the beginning of emergency evasive action, such as braking (allowing for reaction time). It is often difficult to find physical evidence however, which will locate this point. It is also very difficult to determine what the participants were doing or thinking which lead to their inattention just prior to the collision. This information, even if obtained, is never recorded.

Although there has been a great deal of research on attention, arousal, alertness, vigilance, divided attention, etc. (which may not all be describing the same thing), there has been little work done on inattention as a distinct concept. This may be due to the difficulties in creating inattention in the lab. There has been work relating the effects of fatigue, stress, and drug impairment on attention levels (Kaluger & Smith, 1970; O'Hanlon & Kelly, 1977). Much of the work on inattention has been based on measuring eye fixations, pupil size, blinking response and other physiological responses such as GSR and heart rate (Beatty & Wagoner, 1978; Beideman & Stern, 1977; Hess & Polt, 1964; Kahneman, 1973). It is obviously quite difficult to create inattention in a driving task while trying to collect this type of data.

Experimenters must therefore rely on performance errors as an indirect indicator of inattention. Some have measured the errors that stem from prolonged driving (Harvey, Jenkins, & Somner, 1975; Reimersma, 1977). Others have examined a driver's ability to perform subsidiary tasks concurrently with driving and measured the decay in performance as the primary task required more attention and/or effort (Brown and

Poulton, 1961). Zaidel et al. (1979) point out that there has been an increasing disenchantment with subsidary tasks as a measure of attentional capacity (Mackie, 1977; Riemersma, 1977). These studies have not, however, addressed why inattention occurs or what can be done about it.

In most driving situations, the operator is constantly inundated with information which must be processed and responded to, requiring that several physical actions be performed simultaneously. Often this information is coming in at a rate of speed far in excess to what the human information processing system is designed to handle and therefore some data must be ignored. While this information is being processed at several different levels, the operator must also maintain a constant vehicle speed and placement within a travel lane. To complicate the task a little further, drivers frequently listen to either a radio or taped music. Many operators smoke while driving, while others engage in sightseeing or carry on conversations with passengers. Most drivers, at one time or another, have some pressing problem on their minds, on which they are focusing a great deal of attention. Almost all drivers, at one time or another, think about other things unrelated to driving throughout much of their trip, if only where they are going and what they will do there. For a large part, the driving task has become almost secondary and automatic.

There are several ways in which inattention can be demonstrated. The danger may not be seen at all, there may be just a momentary lapse slightly decreasing the distance between the point of actual and possible perception, or the person may look at the danger but not 'see' it. The first two may represent response blocks which are brief lapses of attention inferred from unusually long response times (Bills, 1931; Teichner, 1968). The latter could represent some type of selective information processing.

The ease of modern driving may contribute much to the problem. Most modern vehicles are designed to make the operator as comfortable as possible. With minimal demands being made, the driving task may not elicit a sufficiently high level of arousal within the operator to maintain an adequate margin of safety. Arousal time must then be added to normal reaction time when facing an unexpected situation. This may cause over arousal or a startle effect, in which the operator may over-react to the situation. This hypothesis could be tested by comparing the difference in collision rates between operators of standard transmission vehicles and those with automatics, providing that the groups could be matched for most other factors. In urban driving situations standard vehicles are much more demanding on the operator than are automatics.

One theory that attempts to explain why drivers are able to navigate known routes with little attention is driver expectancy (or stimulus-response compatibility), which relates to those features of the roadway that prepare the driver to execute a task and keep him/her prepared until the task is executed (Hutchingson, 1981). From experience, the driver has developed certain informational needs and expects to be provided with certain types of information that will meet those needs. One also expects information to be displayed in a particular way and at precise times and locations so that it can be easily understood and acted upon. Whenever the information provided is in violation of these expectancies, the traffic system becomes less efficient and driver errors become pronounced and may eventually lead to collisions. We expect vehicles to signal lane changes, and move in a logical manner. We don't expect people to drive through red lights, or traffic lanes to end without warning. Road users can quickly become creatures of habit, and any unexpected occurrence can have pronounced consequences.

The degree to which attention can be distributed has been examined quite extensively. Shinar (1978, p.75) stated that the reason drivers do not allocate all of their attention to the driving task, all of the time, is simply because it requires more effort than is merited by the perceived risk of being involved in a collision, at any given time. As this perception of risk increases then so will the allocation of attention to driving. It has been shown that experimental subjects are willing to drive with their eyes closed for longer periods of time when driving under open road situations than when driving in dense traffic (Safford, 1971). Task loading studies have shown that drivers can perform additional mental tasks quite easily under driving conditions requiring low attentional demands without interferring with the driving task. However, this ability quickly deteriorates when one task or the other becomes more demanding (Brown, 1965; Kahneman, Ben-Ishae, & Lotan, 1973; Milhal & Barrett, 1976).

It has been postulated that there is a hierarchy of driver tasks. Positional or control tasks are associated with maintaining the vehicle on the roadway. Situational tasks are associated with interacting with traffic and maintaining a particular headway clearance with respect to other vehicles. Navigational tasks are those involved in route planning and maintaining a certain course so as to reach a destination. It is argued that this hierarchy follows the above order and that in a conflict situation the driver will revert to negotiating the more basic task. The most basic is the positional task of staying on the roadway and not having a collision. This means that if a person misses a turn-off then the driver will likely continue on and not risk a collision in an attempt to back-up. However, many collisions are caused by such maneuvers. While there may be some validity to this theory, it will require more research to demonstrate how and why the tasks interact.

As mentioned previously, road user behaviour can be quite complicated and diverse. Various levels of decision making, risk taking, and attentional demands contribute to any given action. At present this field lacks a predictive theory which satisfactorily explains road user behaviour and which can unite and direct research and countermeasure activity. To this point the emphasis has been primarily on the road user and ways of modifying his/her behaviour. Yet the road user is not the only factor in a transportation facility although he/she may be the most flexible one. It would seem logical, however, that any traffic model to be comprehensive must contain at least elements of the entire ergonomic system.

CHAPTER III

ALTERNATIVE APPROACHES TO TRAFFIC SAFETY

ERGONOMIC APPROACH

Henderson (1971) states that the transportation system is too complicated to be viewed in a fragmented fashion and that it is necessary to establish a framework in which various components of the system can be placed in proper perspective. Many other researchers have also called for a more comprehensive approach, saying that the argument of human error is a cop-out which sets the road-user up as a scapegoat for less than perfect vehicles, road systems, driver education programs, license testing, and traffic legislation (Anderson, 1976; Haddon, 1972; Nadar, 1982; Rumar, 1983).

It is too easy to place the entire blame on the driver. This same emphasis focused industrial safety solely on the human worker for decades. Most companies felt that industrial accidents could be eliminated through increased vigilance and training. It was soon evident that these practices were not making a sufficient impact on the problem. Further investigation showed that even the most vigilant, motivated, and well trained individuals would eventually make a processing or behavioural error if a task was repeated often enough. Once the focus for safety was removed from human requirements and placed upon the environment in which the problem existed, there was a dramatic improvement. The ergonomic approach stresses the relationship among the human element, the machine, and the working environment, and ways in which that relationship can be improved. As a result equipment and working conditions were modified to meet human needs, rather than requiring humans to adapt to the job demands. Such changes included safety guards on the equipment, readouts and control knobs easily differentiated and reached, and increased start up requirements to ensure attentiveness instead of presuming it (Hutchingson, 1981, Chap 3).

A similiar mental stumbling block retarded the cure of endemic cholera. Since cholera was peculiar to the lower socio-economic classes, it was considered to be a result of their lifestyle and squalid living conditions. A great deal of futile effort was expended on encouraging the victims to change their lifestyles in order to eliminate the disease. Once the real cause was determined, control of the environment, water purification and construction of sewage systems quickly overcame the problem. The same was true for malaria, smallpox, and many other fatal diseases. This same philosophy of examining a problem within its environmental context may be equally effective in resolving the traffic safety problem.

Haddon & Baker (1981) and Henderson (1971) both indicate that collisions are not simply a series of unrelated events but a "manifestation of breakdown in the system within which man and harmful agents coexist in a given environment" (Henderson, 1971 p.3). It is important therefore to analyze the entire system from a public health, injury control perspective. Haddon and Baker (1981) write that "the fundamental tasks in injury control are (a) to prevent the (potentially injurious) agents (in this case, of mechanical energy) from reaching people in amounts or at rates that exceed injury thresholds, and (b) to minimize the consequences of injury" (p.4).

Haddon states that "highway safety is a social issue, not because vehicles crash, but because of the losses in damaged people and property (1972, p.193)." Simply because vehicular transportation is such a common practice in our society does not mean that the harmful consequences of that transportation should also be accepted as common and inevitable. According to Alberta Transportation Safety stats there were 4,278 lives lost, and over 246,000 persons injured in Canada due to traffic collisions during 1985. The total property damage is unknown, but is likely in excess of $75 million. If this were any other disease, a state of medical emergency would have been declared quite some time ago and traffic collisions considered an epidemic.

Traffic collisions are very predictable events arising from certain actions, with the consequences being controlled by physical laws. In epidemiology terms injuries sustained in collisions are the result of a transfer of mechanical energy to a human participant or host. The vector, or carrier, of this mechanical enery is most often a motor vehicle. Having established the vector, the agent, and the host of this disease process, it should be possible to devise ways to control it.

Each collision passes through certain phases where countermeasures may be taken. The pre-crash phase is concerned with prevention of the collision through behaviour modification and system design. The crash phase starts with the collision itself and is concerned with the prevention and reduction of injury by protecting those involved. The post-crash phase is concerned with the minimizing the effects of injuries already sustained through quick emergency response and medical attention. Haddon and Baker (1981) have proposed ten interrelated approaches to reducing any kind of injury process, including traffic collisions (Table 3). A specific strategy will usually concern itself with a specific phase of the collision event.

Any and all of these stategies could have a place in a comprehensive collision reduction program which should employ countermeasures addressed to each of the three crash phases. The selection of countermeasures should be determined by giving priority to those that will most effectively reduce injury losses. Preference should also be given to passive measures that will work automatically. Although seatbelts are effective in reducing injury and deaths in crashes, they require the occupant to use them on every trip. Airbags do not have this limitation. If vehicles are not allowed to exceed a certain speed, then they should not be able to exceed that speed. If headlights should be on to increase visibility, then they should be tied into the ignition system. Rules, regulations, and sanctions cannot be expected to eliminate specific behaviours if constant vigilance is required.

The alternative to automatic devices is public education into their correct use and continuous efforts to increase compliance. There has been some recent evidence to indicate that driver education may not have an appreciable effect on driving skill or collisions. In fact it tends to encourage teenagers to get their licenses earlier, increasing overall collision rates. A major source of public education is through safety campaigns.

TABLE 3
Approaches to resolving traffic problems proposed by Haddon and Baker (1981)

1. Preventing the marshalling of potentially injurious agents, i.e.forbidding the manufacture and sale of motor vehicles. Banning alcohol would also fit into this section as a means of eliminating impaired driving.

2. Reducing the amount of the agent. This would entail limiting the speed of motor vehicles.

3. Preventing inappropriate release of the agent. This includes any program, such as enforcement, driver training, and media campaigns designed to reduce the number of collisions.

4. Modifying the release of the agent to non-injurious levels. The use of seatbelts, which decelerate occupants with their vehicles rather than permit more abrupt decelerations against hard surfaces.

5. Separating in time or space the agent and host. Any device which reduces the opportunity for the host to intersect with the agent, eg. bicycle paths, elevated pedestrian walkways, and increased drinking and driving ages.

6. The use of physical barriers such as motorcycle helmets or guard rails which may attenuate or totally block the harmful force.

7. Modifying surfaces and basic structures. Use of airbags to delocalize energy by spreading it over a wider area of the body, removal of sharp or hard surfaces within a vehicle and modifying streetlights and signposts to yield or break away upon impact.

8. Increasing resistance to injury. Requiring increased health and physical fitness standards for road-users.

9. Begin to counter damage already done. Increase response time of emergency vehicles, training of emergency personnel, medical supplies and life support facilities at scene and in transit.

10. Stabilize, repair, and rehabilitate the injured. This includes some of the procedures of strategy nine, but focuses more on the level of medical care available. Approximately 10-20% of urban fatalities occur after the injured person has arrived at the hospital. In some cases death-causing complications did not occur for several days or weeks after the crash.

SAFETY CAMPAIGNS

While enforcement can be a powerful tool in modifying behaviour, it is made more powerful if people are aware of its existence. General deterrence depends on the fact that people are aware of the potential risk. This includes not only detection and punishment if an offence is commited, but also the risk of a collision. The message is communicated most effectively by the media, and as such, the media are used frequently for various safety campaigns and messages.

Millions of dollars are spent annually in Canada on various traffic safety campaigns. Millions more are donated as public service time by various media groups. These campaigns represent a variety of message formats- threatening, informing, pleading, whimsical- as well as different message contents; drunk driving, speeding, seatbelt use, and many others. Although a great deal of time and effort goes into creating these messages, there is very little done to evaluate their effectiveness.

Communication theorist David Berlo, states that "All communication behaviour has as its purpose the eliciting of a specific response from a specific person or group of persons" (1960, p.6). If the goal of a safety campaign is to increase or decrease the incidence of a specific behaviour in a specific group, then the success of that campaign should be some measurable change in the behaviour. Yet such measurements are seldom done. The accepted criterion for a message is frequently its face validity, i.e., whether the message is plausible and meaningful and whether test groups understand and remember the contents.

Generally, these campaigns contain either a report on statistics related to a specific behaviour, a judgement on the acceptability of that behaviour, or both. Impaired driving campaigns often quote the number of people killed or seriously injured in alcohol-related collisions (usually labelled as alcohol caused) with an emotional statement on how criminal, dangerous, stupid, and senseless it is to drink and drive. They may focus on the number of people who have been charged, convicted, suspended, and/or jailed, quoting the maximum penalty that an impaired driver can get for his/her offence (although the average penalty is far less). Despite these impressive statistics, there has been little, if any, work done on how people react to this approach.

A knowledge of the motivations underlying a behaviour is critical for a specific campaign to be successful in changing public attitudes (Katz, 1960). There is wide support for this concept in learning and motivation theories. People engage in various behaviours to meet specific needs and wants. In order to stop people from speeding, drinking and driving, and other dangerous behaviours, there must be an adequate understanding of the motivational forces behind these behaviours.

It is also important to consider human defense mechanisms. Drunk driving campaigns invariably focus on death and severe punishment as a consequence of impaired driving. They also label impaired drivers as stupid, insensitive, dangerous criminals. Most people would find it difficult to identify with this portrayal. A majority of the population will drink and drive at one time or another, and a substantial number will do so on a regular basis. Since these people cannot identify with their portrayal in the campaign, they will be unlikely to accept the message.

To be successful, a campaign must realistically portray the problem and those involved. It must acknowledge the legitimate reasons for the behaviour and then offer an acceptable alternative. The campaign must also present itself to its target audience at an appropriate time where they can act upon the message. Festinger (1957) indicated that significant changes in attitude can be obtained if an individual could be persuaded to behave in a manner compatible with that attitude. He also showed that people will reject messages that are incompatible with their present attitudes.

If action is important for successful behaviour adjustment then most print and television campaigns should have little impact on driving behaviour. Robertson (1970) demonstrated this in an in-depth analysis of a seatbelt campaign. The U.S. National Safety Council expended about

$51 million in public service time for a 1968 seatbelt promotion. Using a twin cable media test suburban community, Robertson discovered that the messages had absolutely no effect on seatbelt use. In this community households were wired with one or the other cable system. Generally the television programming was identical but commercials were different. In this case only one cable group saw the seatbelt messages over a nine-month period. Vehicles were then observed leaving the area and the licence plate and seatbelt use were recorded. The address registered to the licence was then used to match the occupants to the control or experimental group. Robertson concluded that, while the message may have been effective while the viewer was watching the television, there was no chance for people to respond to it until the next time they drove, by which time the impact was lost.

It would seem that the medium used is at least as important as the message. Learning theories have shown that behaviour should be linked to a stimulus fairly closely in time to be effective. There has also been evidence to support the idea that learning of a behaviour is greatest when done in the environment in which it will be performed. For behaviours like impaired driving, there is also the consideration of state dependent learning. A message that a person has learned while sober is likely to lose its impact when that person is intoxicated (over and above the obvious decrease in mental functioning caused by alcohol consumption). It is therefore necessary to concentrate on those media that reach the target population while they are driving, or drinking, or both.

A poorly designed or ineffective campaign can sometimes be worse than no campaign at all. McGuire & Papageorgis (1961) developed an inoculation theory showing that when an argument is successfully refuted in an ineffective campaign, then the target audience is more resistant to subsequent messages. The individual becomes more secure with his/her initial position, making further attempts to counter it less potent than they might otherwise have been.

It may seem at this point that traffic behaviour is too complicated for a comprehensive theory to be developed and that any countermeasures taken will at best be hit and miss. Unfortunately, this seems to be the attitude taken by many of the people working in the traffic safety industry with the collision rate being the price that must be paid for the benefits of a transportation system. There are, however, programs that appear to be working.

OTHER ALTERNATIVES

While not insoluble, the traffic safety problem is immense in proportion and is likely the largest single safety problem we face. The fact that it can be reduced is readily apparent from recent, dramatic decreases. In 1983, property damage collisions within Calgary fell 23% over 1982 and injury collisions dropped 35%. These rates stabilized during 1984. It is believed that the economic downturn was a significant factor in these decreases but it is not known why or how. The most likely answer would have been either a decrease in the number of vehicles operating within the city or the amount that they were used. Job cutbacks might have resulted in fewer people commuting by personal vehicle. There may have been less money available for after work activities which required a vehicle. If there was a decrease in vehicles, they did not simply migrate somewhere else, since similar decreases were experienced all across the country. Police enforcement increased considerably in 1983 with a greater emphasis on selective enforcement which may also have had an impact. The real cause for the decreases is likely a combination of all of the above plus several other factors.

Although there are several theoretical reasons for the decreases, there are very few data to support any of them. Did traffic flow decrease? This is unknown because fewer volume counts were done that year due to lay-offs. Was enforcement successful? If so, then there should have been a decrease in offences, but this information is not recorded. Was any particular type of collision reduced more than others? This is also unknown because the computer systems used to store the data are limited as to what information can be retrieved.

It has already been indicated that the goal of enforcement is the decrease of behaviour that can cause traffic collisions. It has also been stated that the purpose of a selective enforcement program is the identification of problem areas and the concentration of enforcement at those specific locations and times. If high risk areas can be identified then attention requirements can also be determined for these locations. If higher attention levels are required then steps can be taken to increase attentiveness by changing the environment. Both violations and collisions should drop as a result. At the very least it can be determined that drivers who do violate are being attentive and are committing the violations intentionally.

One such program conducted in England by the Transport and Road Research Laboratory (Helliar-Symons, 1975) used road markings to slow traffic down at the approach to traffic roundabouts. It was found that vehicles were leaving high speed freeways onto these roundabouts at too fast a speed. The markings consisted of a series of yellow thermo-plastic lines which transversed the roadway with the distance between lines gradually decreasing. These lines not only stimulated attention but also had an effect on speed adaptation through a visual illusion of acceleration.

Speed adaptation impairs a person's ability to determine subjectively vehicle speed after travelling at a high speed for a sustained period of time. Under normal conditions people are fairly accurate at speed estimation (Barch, 1958; Denton, 1966; Schmidt & Tiffin, 1969; Shinar, 1978) which is performed by analyzing the movement of scenery in the peripheral visual field. After sustained high speeds, however, the peripheral field becomes accustomed to this rapid movement and loses its ability to evaluate lesser speeds. Denton (1966) found that when drivers were asked to halve their speed from 100 km/h, without the aid of a speedometer, they tended to settle at 70-75 km/h. Subjects found that driving at a more moderate speed seemed exceedingly slow.

Since speed evaluation is done largely by perception of movement in the peripheral field, it was postulated that a visual illusion of acceleration could compensate for the speed adaptation. With progressively diminishing distances between the lines, the subject would see the lines passing under his/her vehicle at a faster rate and perceive that the vehicle was going faster. Denton found that when subjects were asked to halve their speed after a sustained 100 kmh, while travelling over the lines, they averaged 40 kmh. Helliar-Symons (1975) followed this study up with a large scale collision study where lines were installed at 50 test locations and collisions were monitored for two years. It was shown that the test sites had a 52% reduction in collisions between the two years prior to and after the lines were installed. The control group of 50 locations had a 14% increase in collisions. A Chi Square analysis found this decrease to be significant at $p<.01$ (X =19.2). One of the experiments in this thesis attempts to look more closely at the effects that this visual stimulus may have on inattention and speeding behaviour.

Another method of influencing driving speeds used by VanHouten, Nau & Marini (1980) in Dartmouth, Nova Scotia, was public posting. A large sign was used giving the number of drivers who were not speeding on the previous day, and the highest or best record to date. This information was obtained by the use of a concealed radar device at two 20-minute intervals Monday through Friday. Public posting as a means of performance feedback has been used effectively in other areas such as mental health (Panyan, Boozer & Morris, 1970), athletics (McKenzie & Rushall, 1974), and education (VanHouten, Hill & Parsons, 1975; VanHouten & VanHouten, 1977). In other areas it was not effective, such as an attempt to increase seatbelt use in Ottawa (Jonah, 1982).

VanHouten et al. (1980) showed a 69% reduction in drivers exceeding 24 km/h over the posted speed limit and a 54% reduction in those exceeding 16 km/h over the limit at the end of 26 weeks. Significant reductions in speed were still being obtained at the same location 20 months later. There was also a reduction in the mean number of collisions from a stable level of 1.56 per month during the previous 24 months to 0.67 collisions per month following the installation of the sign. They do not mention the variance, however, nor whether this 57% reduction in collisions is significant. The experimenters claim that public posting is effective for three reasons;

1. It draws attention to the speed limit and to the driver's speed
2. It indicates that the majority are NOT speeding, thereby putting subtle pressure on the driver to conform to the norm
3. It implies that someone, perhaps the police, is monitoring a driver's speed.

In a follow-up study (VanHouten & Nau, 1982) the sign was used in several different locations and a variety of conditions. It was found that the sign was most effective when the percentage not speeding figure was over 80%. This can be modified by the criterion used to define speeding. It was also noted that compliance fell when the numbers on the sign did not change for several days. People had to believe that traffic was being monitored. A third study demonstrated that the effects of the sign deteriorated with increasing distance from the sign, however, residual effects could be noted for up to 6 kilometers downstream.

While this method seems to have been extremely successful for VanHouten et.al. in Nova Scotia, it is not certain that it will be equally successful in other locations. In 1982, Wilde replicated this study in Kingston but did not obtain any significant changes in either speed violations or collision frequency. VanHouten's weak analysis of collision data and his small sample sizes also raise some concerns about the effectiveness of this technique. Replications in other areas and larger samples will be necessary to validate it properly. One of the experiments in this thesis attempts to do just that.

There are many other potential means of altering driver behaviour through control of the environment. Armour (1984) showed that speeds could be reduced by limiting street length and street width. Marconi (1977) found that mini-roundabouts and an increased number of stop signs could reduce speed within residential areas. Unfortunately both of these ideas can lead to other traffic problems and would reduce the overall efficiency of the transportation system. Any device which directs the driver's attention to the road and the environment, however, should be researched carefully, as it may be quite effective. By reducing the number of inattentive drivers at critical areas, not only will offences and collisions be reduced but the effectiveness of enforcement will be enhanced by concentrating police activity on those drivers who are deliberately involved in risk taking.

An environmental cue that deserves special mention is the traffic signal. As of January 1, 1986, there were 458 traffic lights in the City of Calgary. Intersections represent a particularly serious traffic risk, since collisions occurring there usually involve one vehicle being struck broadside. This is the most vulnerable part of a motor vehicle and occupant restraint devices are not designed to protect occupants against this type of impact. In fact, seatbelts may contribute to injuries and death by holding occupants closer to the point of impact. In Calgary, during 1985, there were 648 intersection-related collisions claiming nine lives and injuring several hundred others. This makes light infractions the single largest factor in injury and fatal crashes.

Another factor that increases the danger of traffic light collisions is speed. Often, offenders speed up in order to clear the intersection more quickly if they feel that they can't stop in time. Even those that violate the light through inattention are usually travelling at least the speed limit. In either case there is little or no braking prior to impact, resulting in a great amount of energy being expended on the most vulnerable portion of the victim's vehicle or, in some cases, on a pedestrian. Injury and/or death are frequent and reasonable consequences of traffic light infractions.

Although the law is fairly clear on the responsibility of a motorist when facing a traffic control light, as can be seen in the following definitions from the Alberta Highway Traffic Act (RSA 1980), there is a general failure for Calgary drivers to comply. In 1985 there were 10,728 charges laid for the following offences;

109(1) When a red light alone is shown at an intersection by a traffic control signal, the driver of a vehicle approaching the intersection and facing the red light shall stop immediately before entering the intersection and shall not proceed until a traffic control signal instructs him that he is permitted to do so.

108(1) When a yellow light is shown at an intersection by a traffic control signal at the same time as or following the showing of a green light, the driver of a vehicle approaching the intersection and facing the yellow light shall stop before entering the marked crosswalk on the near side of the intersection or if there is no such marked crosswalk, then before entering the intersection unless such a stop cannot be made in safety.

In both cases the driver is expected to stop. Yet many drivers charged with yellow light violations were unaware of this requirement. Many driving schools teach that the yellow phase means to clear the intersection. The actual design of the phase is first to notify drivers that their green phase is over and to give sufficient warning of an impending red phase in which opposing traffic will have right of way. When the light turns red the intersection should be empty.

To be effective, the yellow phase must be of sufficient intensity and duration for all drivers to see it and be able to stop safely. There have been a number of studies measuring placement, intensity, color content, and construction of the traffic signal for optimal visibility (Baerwald, 1976; Forbes, 1972; Wells, 1970). These studies have lead to the creation of standards for traffic light construction. There have also been studies done on signal light duration which are not quite as conclusive (Konecni, Konecni, & Ebbesen, 1976; Olson & Rothery, 1972; Pignataro, 1973;

Williams, 1977).

In Calgary, the yellow phase is being standardized to four seconds. If more time is required, usually on roads with speed limits of 70 km/h or more, the norm is to add an all-red phase of 1-3 seconds. City engineers believe that to increase the yellow phase would decrease its effectiveness and condition drivers to enter two to three seconds after the yellow onset. There is very little research to support this claim, however. Generally, light timing is determined by testing average reaction time and braking distance under a variety of deceleration rates. Vehicle stopping distance will vary depending on several factors such as the roadway's coeffecient of friction (which changes with weather and age of road surface), the type and condition of tires, braking efficiency, and the presence of power brakes. In the real situation, however, both perception and reaction time will vary considerably from one person to another and even the same person will react differently on different occasions and in under different conditions. The major variable that will change is the driver's attentiveness to the situation and his/her desire to stop. Two experiments in this thesis examine the behaviour of motorists at traffic signals. One particularly examines a driver's desire to stop.

Unlike most traffic infractions, traffic light violations involve a random element. A driver has to be a certain distance from the intersection when the light turns yellow or red in order to commit the violation. The usual method of investigating light violations is to observe an intersection and record the number of persons who fail to stop (Booth, 1977, 1980). There is usually no emphasis given to where the offender was at the time of onset, vehicle speed, traffic volume or placement, the absence or presence of other vehicles that may act as models, or the reason that the driver committed the violation. On occasion the entire sequence is filmed so that these variables can be determined (Williams, 1977). Some program designed to decrease violation, such as enforcement, is then introduced and the change in violations noted. One question that these studies don't address is the behaviour itself. What degree of risk will drivers accept in violating the lights?

The research cited above offers a strong case for an increased emphasis on the road user's relationship with his/her environment. The work done by VanHouten and Helliar-Symons demonstrates that relatively minor changes in the environment can have major, positive effects on driver behaviour. Both have been replicated in the first two experiments in the next section using larger sample sizes and more accurate speed measuring devices. Both studies examine the role that a visual stimulus can have in changing behaviour through increased attention of drivers. VanHouten's public posting also adds a low level threat of enforcement.

Generally the research on enforcement has indicated that it has a positive effect on behaviour but there is still considerable debate over its residual and halo effects. The effects of enforcement on speeding behaviour have been extensively tested. There has not been the same amount of work done on traffic light infractions which tend to be a more pressing concern due to injury severity. The final two experiments in this study examine traffic light infractions in detail and use turn violations at a sign controlled intersection for comparitive analysis. Although the four experiments do not all investigate the same problem under the same conditions, they are complementary, since each examines an important, but slightly different aspect of driver behaviour. Each independent variable also contains a different level of risk and therefore contributes to the examination of risk taking versus inattention as the principle cause of traffic safety problems.

CHAPTER IV

EXPERIMENT 1- DIMINISHING LINES

One of the major premises of this thesis is the influence of inattention on driving behaviour, related to traffic offences and collisions. Earlier it was posited that inattention may be a cause of speeding in places where the speed limit changes from one speed to a lower one. The present experiment tests this hypothesis by measuring the impact of a strong visual stimulus on speeding. The stimulus used was a series of reflective white lines painted tranversely across an exit ramp from the Deerfoot Trail freeway to 16 Avenue N.E., similar to those used by Helliar-Symons (1975). It has been demonstrated that the use of these lines has been quite effective in reducing speed, particularly if speed adaptation has occurred (Denton, 1966; Helliar-Symons, 1975).

Although speeding was definitely a problem at the intersection chosen for this study, it is unlikely that speed adaptation was a significant cause. As mentioned earlier, drivers must be operating at high speeds for a sustained period of time (at least 20 minutes) for speed adaption to occur. The vast majority of drivers on this roadway are from Calgary and would not have been on the freeway long enough to be adapted. It is, however, likely that inattention was a principle factor. Since the lines were highly visual, it was expected that they would increase arousal and attentiveness of the drivers using the ramp. If the speeding behaviour was subsequently reduced, then this could support the view that inattention was a factor contributing to the original problem.

Method

Subjects. Speed measurements were collected over a 5.5 week period, for a total of 752 hours of data. The speeds were collected on motorists travelling the 900-meter southbound exit ramp from the Deerfoot freeway to the 16th Avenue split diamond interchange. A total of 247,036 vehicle speeds were recorded. The drivers involved were unaware that they were participating in a speed study and that their speed was being recorded.

Apparatus. Speed and volume were measured using a Stevens PPR II Print-Punch Traffic Classifier, manufactured by Leupold and Stevens Inc. This instrument is a microprocessor controlled, electromechanical recorder that converts output pneumatic pulses from rubber hoses to a printed record. Two quarter-inch hoses were laid perpendicular to the traffic flow, 4.88 meters apart. Impulses were stored in memory and then printed as a summary for a specific time interval in standard ASCII punched format on 2.5 cm. heat sensitive paper tape. For this study the time interval was one hour, meaning that all vehicle speeds were averaged over a one-hour period.

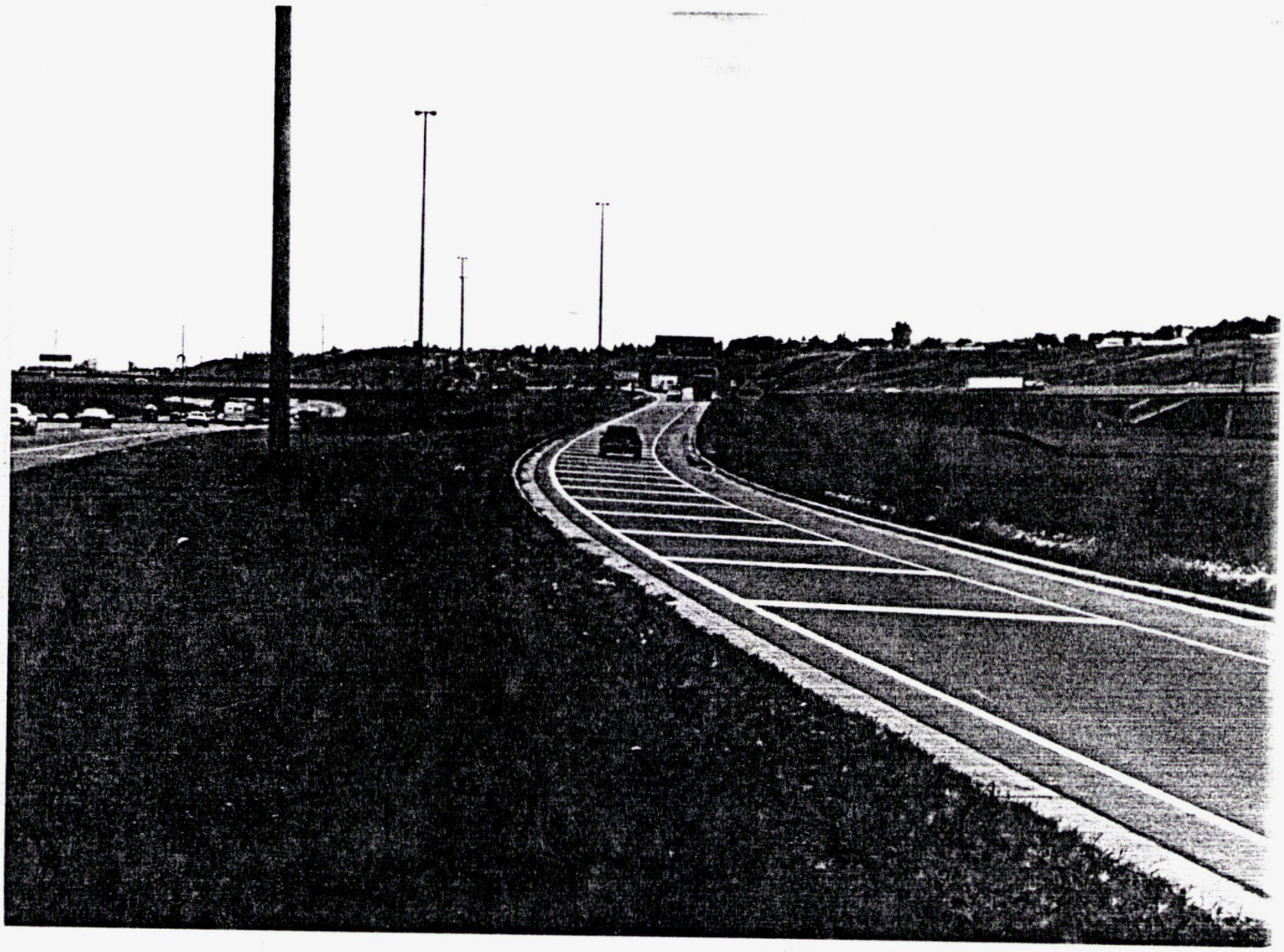
Procedure. The southbound exit ramp of Deerfoot Trail and 16 Avenue N.E. was chosen for several reasons. One, the ramp had a advisory posted speed of 50 km/h, which was considerably less than the posted speed limit of 100 km/h on the freeway. This was an advised speed limit only, so there was no legal compulsion for drivers to travel at that speed. There were also no design features that required the driver to slow down, so that drivers could operate at any speed desired given free flow conditions. Any reduction in speed should therefore reflect a change in driver decision making. Two, it approached a signal-controlled intersection that had a high collision rate. Three, a speed problem on the ramp had been independently identified through collision investigation and direct observation. Finally, the ramp was a straight, long, single lane road which made it ideal for the painting the lines and installing the data collection equipment.

On April 28, 1982, the classifier was installed 130 meters upstream of the traffic control light (770 meters downstream from the beginning of the ramp). Data were collected until May 16, which formed the pretest baseline phase of the study. Vehicle speeds in each hour were averaged by the classifer to obtain a score for that hour. The number of vehicles in each hour ranged from four to 865 with an average of 328 vehicles. There were 336 hours of data collection (106,444 vehicles or 318 per hour) in the pretest baseline group.

The ramp was then closed for approximately eight hours while 90 fluorescent white lines were painted transversely on the ramp over a 404 meter distance (figure 1). Each line was 60 centimeters in width and four meters in length (curb to curb). The distance between the lines gradually decreased from 7.7 meters at the start to 2.75 meters according to the specification outlined by Helliar-Symons (1975). The lines started 100 meters after the ramp began and finished 400 meters from the traffic light. After the lines were installed, data collection continued until June 5. There were 416 hours of data collection (140,622 vehicles or 338 per hour) in this group. Since traffic patterns change during the summer months with an increase in holidays and visitors, it was felt that continued data collection would not likely be useful during these months.

In both phases of the experiment, data collection was not continuous. The most common reason for lost data was either a break in one of the hoses or condensation following a rain or snowfall. Several hours of data recorded during snow or rain storms were also omitted, as they were unrepresentative of the driving conditions. In phase one 68 hours from a total of 404 hours (16.8%) were lost. In phase two 60 hours from a total of 466 (12.6%) were not reported. Breaks (due to street cleaning) were more of a problem in phase one than in phase two, where condensation seemed more prevalent. The hoses were checked every morning and if necessary

FIGURE 1
Diminishing Lines Installation



replaced promptly so that only small blocks of time were lost. The damage was primarily confined to early morning hours or weekends. Overall the weather was relatively consistent throughout the study. Although there was slightly more snowfall during the pre-test phase, the ramp itself did not ice up and there did not appear to be a weather-related effect on speed.

A pre-post design was used in this experiment, since a suitable control site was not available. Data were collected on the northbound ramp of the same interchange for control purposes but there were significant differences found between these two ramps in the pre-test phase. The northbound ramp was designed differently and had a different traffic pattern. Other interchanges along the freeway had to be ruled out for similar reasons.

RESULTS

Two dependent variables were measured in this study, mean speed and the percentage of vehicles over 80 kmh (30 kmh over the advised speed limit). The latter was of interest because it was considered a high risk for collisions and thus a desirable target for speed reduction. Significant decreases in both were found, using a one-tailed T-test and the Mann-Whitney U test, as a result of the diminishing lines ($t = -2.64$ for mean speed and -3.73 for % over 80, $df=285$, $p<.001$). The results are detailed in Table 4. Table 5 indicates that the effects decayed over time.

TABLE 4

The Effect of Diminishing Lines on Speed

	Mean speed	Over 80
Before lines	63.46 km/h	5.45%
After lines	61.44	4.06%
% difference	- 3.3	-25.5
T value	- 2.64 *	- 3.73 *

* $p<.001$

TABLE 5

Comparision of Post-test condition

	Hours of data in week	Mean Speed	% over 80 kmh
1st week	148	60.43	3.19
2nd week	130	61.89	4.55
3rd week	138	62.09	4.50
Total	416	61.44	4.06

The pre-test and post-test data were also compared by day of week and hour of day to determine if the effects were consistent. The data from each day of the week for which there was a complete 24 hours of data were averaged to obtain a daily score. An hourly score was obtained by averaging all like hours together regardless of day of week. This analysis indicated that the decrease in the dependent variables was fairly consistent over each day of the week (except Friday) and over each hour of the day. Tables 6-9 summarize these results.

DISCUSSION

The results support the hypothesis that a strong visual stimulus can result in a reduction in speed. This particular stimulus has been shown to be quite effective in reducing the effects of speed adaptation (Denton, 1966; Helliar-Symons, 1975) and produced a significant startle effect. Since it is unlikely that speed adaptation is an issue here, it is assumed that the startle effect of the lines increased overall attentiveness. As drivers paid more attention to their surroundings they also reduced their speed to comply more closely with the advised speed limit. The data also show that this reaction was consistent across both hours of the day and days of the week, except for Friday.

It is also assumed that drivers who are most inattentive would not decrease their speed until forced to by the traffic

TABLE 6

Mean Speed (km/h) by Day of Week

	Before lines	After lines	% difference
Sunday	64.82	62.56	- 3.5
Monday	63.87	60.75	- 4.9
Tuesday	64.26	61.05	- 5.0
Wednesday	63.64	61.05	- 4.1
Thursday	62.76	61.36	- 2.2
Friday	62.15	63.36	1.9
Saturday	63.97	62.25	- 2.7

TABLE 7

Percentage of Vehicles That Exceeded 30 km/h

Over the Recommened Speed Limit by Day of Week

	Before lines	After lines	% difference
Sunday	6.92	4.00	-42.2
Monday	6.00	3.48	-42.0
Tuesday	5.09	3.58	-29.7
Wednesday	5.75	3.53	-38.6
Thursday	4.89	4.25	-15.1
Friday	4.18	4.30	2.9
Saturday	5.97	5.42	- 9.2

TABLE 8

Mean Speed (km/h) by Hour of Day

Hour	Before lines	After lines	% Difference
0001-0100	62.61	58.95	- 5.8
0101-0200	60.50	59.07	- 2.4
0201-0300	60.71	59.01	- 2.8
0301-0400	63.00	62.00	- 1.6
0401-0500	62.60	60.46	- 3.4
0501-0600	65.03	64.78	- 0.4
0601-0700	67.14	66.62	- 0.8
0701-0800	64.10	61.36	- 4.3
0801-0900	64.37	61.86	- 3.9
0901-1000	65.14	63.17	- 3.0
1001-1100	64.28	62.55	- 2.7
1101-1200	64.02	62.36	- 2.6
1201-1300	63.85	61.62	- 3.5
1301-1400	63.34	61.34	- 3.2
1401-1500	63.13	61.00	- 3.4
1501-1600	63.24	60.88	- 3.7
1601-1700	62.95	60.97	- 3.1
1701-1800	64.60	62.49	- 3.3
1801-1900	65.92	63.16	- 4.2
1901-2000	65.80	63.07	- 4.1
2001-2100	64.46	62.35	- 3.3
2101-2200	61.96	61.04	- 1.5
2201-2300	60.34	57.89	- 4.1
2301-2400	60.22	58.73	- 2.5

TABLE 9

Percentage of Vehicles That Exceeded 30 km/h

Over the Recommended Speed Limit by Hour of Day

Hour	Before lines	After lines	% Difference
0001-0100	6.71	3.81	-43.2
0101-0200	3.83	3.87	1.4
0201-0300	5.13	4.40	-14.2
0301-0400	8.56	4.07	-52.5
0401-0500	9.25	5.49	-40.6
0501-0600	9.71	9.99	2.9
0601-0700	9.93	9.32	- 6.1
0701-0800	6.87	4.22	-38.6
0801-0900	5.92	3.69	-37.7
0901-1000	5.66	4.01	-29.2
1001-1100	3.98	4.01	0.8
1101-1200	3.74	3.00	-19.8
1201-1300	4.30	3.23	-24.9
1301-1400	3.58	2.59	-27.7
1401-1500	3.90	2.25	-42.3
1501-1600	3.39	2.57	-24.2
1601-1700	3.37	2.78	-17.5
1701-1800	5.02	3.95	-21.3
1801-1900	6.52	4.36	-33.1
1901-2000	6.19	4.25	-31.3
2001-2100	5.11	3.87	-24.3
2101-2200	3.70	3.44	- 7.0
2201-2300	3.53	2.13	-39.7
2301-2400	3.23	2.54	-21.4

lights. This group would most likely be exceeding 80 km/h. As such, an increase in attentiveness should be highly pronounced in this group. The data support this conclusion as evidenced by the 25.5% decrease in this category. This is a decrease of 764 fewer vehicles a week exceeding 80 km/h, given an average daily volume of 8,000 vehicles.

The major drawback to this stimulus is indicated in the decay of the speed reduction effect. The lines performed extremely well in the first week and then the effect dropped off. Continued monitoring of speed might have revealed a return to the baseline rates or a plateau somewhere in the middle. As mentioned, monitoring was discontinued in June due to an anticipated change in the traffic mix during the summer months. These months usually bring an increase in out-of-town visitors due to holidays and other factors that would confound the data. It is suggested that this decay was brought about by drivers learning that the lines were there and anticipating them. This reduced the startle effect such that it could be ignored. There was also no compulsion on motorists to drive at 50 km/h, since the speed limit is advisory only.

Another confounding factor was the presence of the traffic lights at the top of the ramp. Many motorists would likely ignore the lines if slowing down would prevent them from reaching the intersection on a green light. Alternatively, the lights may have slowed down some drivers that otherwise would have continued with their high speed. Although this effect should have been constant across both phases of the study, its effect was not monitored.

In conclusion, the results of this study support the use of these lines to decrease speeding behaviour. Further work will have to be done to validate this effect, particularly in areas where drivers are required to slow down, but frequently do not. It would also be useful to select an area that is not effected by other traffic control devices. An ideal location for further testing would be playground and school zones where there is a high offence rate but also strong legal and social pressures to comply with the speed limits. The fact that drivers speed in such areas despite these pressures could indicate a high level of inattention.

CHAPTER V

EXPERIMENT 2- PUBLIC POSTING

The previous experiment demonstrated that increased attentiveness can result in a decrease in speeding behaviour. It has also been shown that an increase in police visibility and enforcement can reduce driving violations (Armour, 1984; Booth 1980; Council, 1970; Joscelyn et al., 1971). Police enforcement, however, is extremely expensive and cannot be maintained at any given location for extensive periods of time. Several studies have shown that, even though enforcement can generate halo and residual effects, these effects are limited (Edwards and Brackett, 1978). VanHouten, Nau, and Marini (1980) suggested a method of associating the threat of enforcement with an attentiveness-increasing stimulus with very positive results. The present study was performed to validate VanHouten's results using more sophisticated data collection techniques and a larger sample size.

Method

Subjects. Speed data were collected over a 3.5 month period on motorists travelling southbound in the 6100 block of 14 Street Northwest. A total of 1,722 hours of speed data representing the speeds of 690,614 vehicles were collected. The drivers in the sample was unaware of participating in a speed study or that their speeds were being monitored.

Apparatus. Speed and volume were recorded using a Stevens PPR II Print-Punch Traffic Classifier, manufactured by Leupold and Stevens Inc. The recording interval for this study was one hour. Each hour of data is an average of the speeds of all vehicles in that hour. The number of vehicles for any hour ranged from six to 982. The independent variable was a large metal sign measuring 1.3 by 2.3 meters. The sign was green with white lettering which read "Percentage of drivers not speeding yesterday" and "Best Record". Below each of these phrases was a space to insert numbers which were approximately 15 cm high. The sign was mounted 2 meters above the ground on aluminum posts that where anchored in cement blocks and placed approximately 2.5 meters from the curb (figure 2).

Procedure. The 6100 block of 14 St N.W. was selected for several reasons. One, previous enforcement had shown that this particular roadway had a high incidence of speeders and that speeding was a major contributing factor to collisions in the area. Two, the speed limit change from 70 km/h to 50 km/h was similar to that used by VanHouten et al. (1980), and replicated for comparison purposes. Three, the narrowing of traffic from two lanes to one in each direction increased the traffic hazard of speeding on this roadway. At the point of narrowing the road was gradually grading uphill coming to a crest approximately 75 meters from the sign. The down grade from the crest was considerably steeper for the

FIGURE 2

Public Posting Sign

first 50 meters. The classifier was installed approximately 25 meters from the crest of the hill. Finally, the area was totally devoid of any structures or artifacts that might obscure the sign from view, or distract the drivers. The sign was clearly visible for several hundred meters.

Data collection began June 12, 1982, and continued to October 2, 1982. A total of 417 hours of data were collected to determine the baseline behaviour. On July 8, the experimental phase started with the sign in place. This phase was divided into two parts; the sign alone and the sign with percentage figures indicating speed. This phase continued until August 17 for a total of 712 hours. The final phase was a post-test measurement during which the sign was removed. This continued for 593 hours until October 2. Table 10 summarizes this breakdown along with the hours of data collected and the number of vehicles in each phase. Table 11 summarizes the results.

During phase two the sign was present without any numbers being displayed. The purpose of this phase was to determine how much impact a large sign that mentioned speeding would have on drivers' speed. During phase three, percentages were changed regularly to reflect average vehicle speed based upon a daily read-out of the Leupold classifier data. The 'yesterday' figure on the sign moved up or down depending on the speed reading and ranged from 79-94%. The 'best record' figure started at 79% and monotonically increased until it peaked at 94%. This number represented the best percentage that drivers had reached to that date. Because the sign was portable it was possible to remove it and then measure what happened when conditions went back to normal (phase four).

Results

The results of the ANOVA (table 12) support the use of this type of stimuli for reducing speed. The sign produced significant reductions across all three dependent variables; mean speed ($F=24.5$, $df=3/1722$, $p<.001$), % of drivers over 65 km/h ($F=53.4$, $df=3/1722$, $p<.001$), and % of drivers over 80 km/h ($F=30.7$, $df=3/1722$, $p<.001$), as indicated by a one-way analysis of variance. Although the posted speed limit was 50 km/h, 65 km/h was used as the cut-off between speeding and not speeding. This speed is specified by the Alberta Highway Traffic Act (RSA, 1980) as the boundary between a $20 and $30 summons and is commonly used as a definition of 'speeding'. Eighty km/h is the next cut-off between a $30 and a $75 fine and is considered to be a high-risk speed for this location. Table 11 summarizes the results of the data analysis. The % difference rows in that table indicate the difference between that phase and the pretest figures.

The data were also tested using a Student Newman Keuls procedure to determine differences between phases. Although the pretest was significantly different from the other three

Table 10

Phases of the Public Posting Study

PHASE	DATES	HOURS OF DATA	NUMBER OF VEHICLES
1 Pre-test	June 12-July 8	417	174,900
2 Sign-Alone	July 8-July 21	149	59,150
3 Sign with %	July 21-August 17	563	214,120
4 Post-test	August 17-October 2	593	242,444
TOTAL	3.5 months	1722	690,614

Table 11

Summary of Results of the Public Posting Study

	PHASE				
	1 PRETEST	2 ALONE	3 WITH %	4 POSTTEST	F-TEST
MEAN SPEED (km/h)	61.5	59.4	58.7	59.1	24.5 *
% difference		3.4	6.5	3.9	
% OVER 50 KM/H	89.8	86.2	83.4	84.7	10.4 *
% difference		4.0	7.1	5.7	
% OVER 65 KM/H	25.2	18.7	15.0	16.4	53.4 *
% difference		25.8	40.5	34.9	
% OVER 80 KM/H	3.5	2.1	2.1	2.2	30.7 *
% difference		40.0	40.0	37.1	

* $p<.001$

Table 12

ANOVA Source Table for the Public Posting Study

Source	df	Mean Square	F value
Mean speed X Phase	3	294.112	24.511*
Residual	1722	11.999	
Over 65 X Phase	3	115342.125	53.395*
Residual	1722	2160.156	
Over 80 X Phase	3	463.577	30.725*
Residual	1722	15.088	

* $p<.001$

phases, the two test phases and the post-test showed significant differences only in the % over 65 km/h condition between phase 2 and phase 3. Neither was significantly different from the post-test.

DISCUSSION

The sign appears to have made a significant impact on drivers' speeds. During the pretest phase, 25.2% of the traffic southbound on 14 Street were exceeding the speed limit by at least 16 km/h. This represents an average of over 2,400 vehicles every day. Of this group, 336 vehicles were in excess of 80 km/h. Yet this area was well enforced by both zone and traffic personnel. During phase 3, the percentage of speeders fell to 15%, a drop of almost 980 vehicles daily or a 40% reduction. The high risk group also fell by 40%, a reduction of 134 vehicles daily.

Another interesting result was the duration of the effect. A substantial decrease across all dependent variables was still observed four weeks after the sign had been removed. While it is possible that some unaccounted for secondary variable was at work keeping the speeds down, it is also possible that the sign made a lasting behavioural change in the regular users of that route. It is also possible that the removal of the sign was, in itself, a sufficient change in the environment to increase attention levels and cause people to take note of their speed and the speed limit signs.

Obviously there are still questions to be answered regarding the use of this tool. From the available literature by VanHouten et.al. (1982), it seemed that there were certain factors that could affect the sign's effectiveness. The sign seemed to lose its impact if the 'yesterday' figure did not change at least a few times a week. There was also a drop if the 'percentage' and 'best record' drop below 70-80%. It appears that the larger the group 'not speeding', the larger the impact that the sign has. It may also be that if the compliance rate is very low initially then the area may be improperly zoned and the sign cannot overcome the resistance. Further work with the sign will have to be completed before these variables can be properly analyzed.

As an aid to enforcement, however, this sign has shown potential for being very cost effective. By setting up this device upstream to an area marked for special attention by radar patrols, enforcement personnel can be fairly confident that those drivers who do violate the speed limit are doing so intentionally. VanHouten et.al. (1982) has already demonstrated that when the sign is coupled with enforcement the impact is longer lasting. If the impact does decay at any time, the sign can simply be moved to a new location for a few months and perhaps replaced by some other device. It is not necessary to tie up expensive data collection equipment to use this device either. Once this study was completed, data for each hour were correlated with daily averages and it was determined which hours of the day were the most representative of the day as a total. This allowed an unmarked radar car to sample vehicle speeds during these times and collect sufficient speed data to change the percentage figures on the sign with a high degree of validity.

A variation of this device was also experimented with in Calgary and showed potential for reducing driver speeds. A large display board (1 meter wide by .7 meters high) was mounted 2 meters from the roadway and 2 meters off the ground. Directly above this board was a standard regulatory speed sign indicating the posted speed limit of the roadway. Attached to the left of the display board was a radar gun. As vehicles entered into the beam of the gun, their speeds were display on the board and could be immediately compared with the posted speed limit sign.

The sign was set up on two roadways for two one-hour intervals each weekday for three consecutive weeks. To prevent theft and to observe the actions of drivers, traffic was visually monitored while the sign was present. Speed and volume data were collected using the Leupold classifier. Observer reports indicate this type of public posting was effective, since many vehicles were slowing down as they passed the sign. Unfortunately, there were several problems in collecting and analyzing the speed and volume data, making it impossible to validate these reports. It is unknown how much of the observed impact of the sign was a result of the message or simply curiosity.

CHAPTER VII

EXPERIMENT 3- ENFORCEMENT

The purpose of this study was to evaluate the immediate and residual effects of enforcement on traffic light and turning offence behaviour at three intersections. The premise of risk-taking theorists is that a certain level of enforcement should result in an immediate reduction of offence behaviour with the residual impact depending on the duration and regularity (Booth, 1977) of enforcement and the frequency with which the same traffic uses the same roadway at the same time each day.

Two of the three intersections were light controlled and selected for their large volume of traffic and high infraction rate, which was determined from previous enforcement and observation. The remaining location was controlled by two signs restricting turns during peak hours. This location also had a high traffic volume and offence rate. As mentioned previously, offence behaviour at traffic lights is influenced by distance from the light, which is a variable. The inclusion of an intersection controlled by a sign was expected to give a better measure of offence behaviour.

Method

Subjects. A total of 18,845 vehicles were observed at the three locations from January 25 to February 25, 1983. None of the drivers involved was aware of the study and it was not determined if the same driver was observed more than once on a subsequent day.

Procedure. Each location was pre-selected on the basis of offence rate and traffic flow. Both had to be relatively high and consistent. Data on each location were obtained from previous enforcement activity. During the study each observation was for one hour each weekday (Tuesday to Friday) according to the schedule outlined below.

Location	Control	Time	Number of Subjects
1 Macleod Trail 17 Ave S.E.	lights	0715-0815	7190
2 Macleod Trail 7 Ave S.E.	lights	1315-1415	7119
3 10 St. 13 Ave N. W.	sign	1600-1700	4536

During week one each location was monitored by the experimenter and the offence rate and traffic volume were recorded during the times mentioned above. An unmarked police vehicle was used for locations one and three parked S.W. and S.E. of the intersection respectively. At location two, the experimenter stood on the S.W. corner. These records were made to establish a baseline.

During week two the experimenter continued to record the offence rate and traffic flow, however, uniformed police officers were also present to issue summonses to offending drivers. These measurements were used to determine the immediate impact that enforcement had on offence behaviour. At locations one and two the police officers stood approximately 50 meters downstream of the intersection where they could not be observed until after the offence had occurred. The number of police officers present ranged from two to three over the four days of enforcement.

At locations 1 & 2 there were four lanes of one-way northbound traffic. Location one was t-intersected by a two-way road from the west allowing northbound traffic to turn westbound. Turns were prohibited at location two, since 7th Avenue is for the sole use of City Transit. Only offenders proceeding straight through were recorded or summonsed. It would have required an additional one or two officers to summons traffic turning westbound onto 17th Avenue at location one. Turning offences would also have been more difficult to determine consistently, because the offender would have to slow considerably to make the turn. It was the experimenter's opinion that the inclusion of turning offences at the traffic lights would confound the data. It should also be noted that turning traffic made up less than five percent of the total traffic volume and there were only three light offences over the four weeks of observation.

Since the police officers could not see the traffic light from their position, the experimenter identified the offending vehicle to them by radio. The officer would then step into the street and signal the driver to pull over. The officer then explained to the driver that he/she was being stopped for committing a red or yellow light offence and then issued with a summons. A consistent criterion was used to determine the offence by the experimenter. If the vehicle entered the intersection on the yellow light and the light turned to red before the vehicle was halfway through the intersection (determined visually by the experimenter), then a yellow light infraction was called. A red light offence occurred if the light turned to red before the vehicle had crossed the first painted line of the upstream crosswalk.

At the sign-controlled intersection the police officers sat in an unmarked police vehicle approximately 50 meters east of the t-intersection. Offenders could only make an eastbound turn and the officers had a clear, unobstructed view. When the offence was made the officer would step into the street and signal the driver to pull over. Once the offence was explained, a summons was issued. It was not necessary for the experimenter to play an active role in identifying offenders.

There was no enforcement during week three, only observation of the offence and traffic rates. These recordings were used to determine the immediate residual impact of the enforcement. During week four there was neither enforcement nor observation in order for traffic to settle back to normal. The observations were then repeated in week five in order to determine if any residual of the enforcement remained.

RESULTS

At each site an analysis of variance was performed across all weeks and a t-test was done comparing week 1 with week 2 and week 2 with week 3. This was done to separate the immediate impact from the residual. For the two light controlled intersections the ANOVA tests (table 14) showed that the only significant effect was on yellow light violations at location 1 ($F=43.9$, $df=3,12$, $p>.01$). The t-tests for this location showed a significant drop between weeks one and two ($t=15.59$, $df= 3$, $p<.01$) and a significant increase between week 2 and week 3 ($t=-5.57$, $df= 3$, $p<.01$). There were no significant difference in turn behaviour at location 3. Table 13 gives a summary of the results of this study at each location.

DISCUSSION

At the traffic light sites, red light violations decreased considerably and stayed down for the rest of the study. Yellow light violations dropped in the enforcement week only and then returned to original levels immediately after. Generally, volume and weather remained constant throughout the study, although there was slightly more snow during the enforcement week. A linear regression compared changes in volume with offence rate and found no relationship at any of the test sites.

Table 13

Summary of light and turn violations

Site	Week	violations for the week		average violations per hour		volume of vehicles
		Y	R	Y	R	
Macleod & 17th SE	1	66	27	16.5	6.7	1708
	2	45	16	11.3	4	1812
	3	62	13	15.5	3.2	1829
	5	54	14	13.5	3.5	1841
	Total	227	70			7190
Macleod & 7th SE	1	63	24	15.8	6	1702
	2	33	16	8.2	4	1661
	3	53	11	13.3	2.7	1851
	5	62	8	15.5	2	1905
	Total	211	59			7119
10 St & 13 Ave NW	1	210		52.5		1125
	2	159		39.8		1135
	3	149		37.3		1110
	5	176		44		1166
	Total	694				4536

Y= yellow light violation
R= red light violation

TABLE 14

ANOVA Source table for enforcement study

SOURCE	df	MS	F
MACLEOD TR. & 17TH AVE			
Yellow lights			
Between	3	123	43.9*
Within	12	2.8	
Red lights			
Between	3	1.58	1.1
Within	12	1.42	
MACLEOD TR. & 7TH AVE			
Yellow lights			
Between	3	79.0	3.21
Within	12	24.58	
Red lights			
Between	3	12.23	1.37
Within	12	8.9	
10 ST. & 13TH AVE			
Turns			
Between	3	179.0	4.11
Within	12	43.5	

* $p<.001$

At the two light-controlled locations there was a high level of variability in the offence rate from one day to another. This is the most likely reason for a lack of significance in the ANOVA tests. As mentioned earlier, a traffic light violation depends on the combination of desire and proper positioning. A much larger sample will have to be obtained before the random effects of position can be dealt with. Alternatively, the traffic light could be manually operated to control for this random effect, however, any enforcement that arises would not stand up in court.

The significant impact on yellow light violations at 17th Avenue does lend support to the position that high profile enforcement can influence driver behaviour. There does not appear to be a great amount of residual impact at any of the locations however. This may be the result of a general lack of consistent and repetitive enforcement at the target sites. If the study was expanded so that enforcement was more regular but at random intervals, then the residual impact might be extended. Another problem may have been the high volume of traffic. For any impact to be visible, there must be a fairly high percentage of the same drivers from one day to the next in the sample. For this reason 17th Avenue may have shown more responsiveness because the observations were made during morning rush hour in which there should have been a high number of regular commuters.

Since the location of 10 Street and 13 Avenue was used more by local traffic and the offence was not influenced by the random variable of position, there was perhaps a better measure of enforcement effectiveness. The results were exactly what would be expected, a high level of infraction which drops substantially when enforcement begins, remains low the week immediately after enforcement and then begins to recover in the third week after enforcement.

Although enforcement is the traditional and primary tool used by police agencies in controlling behaviour, it does not appear to be effective over the long term. Also, enforcement is intended to effect the intentions of the violator, yet vehicle positioning is a major factor in light violations and can cause considerable variance in the offence rate from one signal cycle to another. This variance has a major influence on whether a program is producing significant results or not despite apparent drops of offences. Future research in traffic light behaviour will have to offset this influence by using a more accurate measure of behaviour as the dependent variable. The following experiment examines a possible approach.

CHAPTER VII

EXPERIMENT 4- YELLOW TRAFFIC LIGHTS

This study was designed to examine the response of drivers to yellow traffic control lights and determine the point at which most of them would stop. Collision statistics indicate that there is a high incidence of light related offences at particular intersections. Given that most traffic lights in Calgary have a four-second yellow phase, there should be very few vehicles unable to stop within this time. Yet, over 2,000 summonses each year, in Calgary, are written for this offence.

Some writers have indicated that the yellow phase causes a great deal of anxiety and confusion to most motorists (Williams, 1977). A more likely answer is that there is a general lack of concern about yellow light infraction. People simply do not want to stop if they do not have to. There have been many attempts made to provide drivers with more information regarding the onset of the yellow phase. The main one is the use of flashing pedestrian crossing signals that become solid when the light is about to change. Unfortunately, this is not standard as yet. In some areas the pedestrian light turns solid just as the light turns yellow, in others there are several seconds before this happens. An inconsistent cue is little better than no cue.

There is also the question as to whether these cues are necessary, since the sole function of the yellow phase is to cue the onset of the red phase. Drivers have ample time to react to this cue and stop. The high offence rate seems to reflect a higher level of risk taking rather than inattention. This is supported by the significant decrease in offence rate that immediately follows enforcement (Booth, 1977). Inattention may contribute if drivers approach the intersection without being aware of the light phase and are caught unprepared to respond when they finally notice that the light has changed. It is posited that by evaluating drivers' voluntary stopping behaviour, baseline standards can be developed to evaluate programs that are designed to reduce the offence rates.

METHOD

Subjects: A total of 160 drivers, evenly divided between four test sites, were involved in this study. None of the subjects had prior knowledge that they were participating in a study. To be selected the vehicle had to be in free flow, which was defined as having no other vehicles within five car lengths to the rear, in the lane(s) immediately adjacent, and none between the test vehicle and the intersection at the time the light is changed. This condition was required so that driver action would not be influenced by the actions of other vehicles.

Apparatus: The traffic signals were the standard non-computerized model installed by the City of Calgary Electrical Division for the purpose of controlling traffic flow. Each signal had been in place for several years and was capable of manual control. A Muni-Quip radar device was used to measure vehicle speed. A Bright Star #1826 flashlight, powered by three Hercules D-size batteries was used as a signalling device.

Procedure: The four intersections selected were in different parts of the city with different traffic volumes and flow patterns. All four intersections selected were standard 90-degree crossings of two two-way roadways. They were:

Elbow Drive and 89 Ave S.W.
Richmond Rd and 37 St S.W.
Fairmount Drive and Heritage Drive S.E.
24 Ave and 19 St. N.W.

Selection was based on manual control capability of the traffic light and moderate traffic volume. Too much traffic would preclude the free flow condition and too little would have required long waits between subjects. Another selection criterion was the placement of the control box. The box would have to be in such a position so that approaching drivers would not discern that the lights were being controlled. It was also necessary for all members of the study team to be able to see one another clearly.

After an intersection was selected, distances representing 3 seconds (41 metres), 4 seconds (55 metres), 5 seconds (69 metres), and 6 seconds (83 metres) travel time to the intersection, at the posted speed limit, were measured off upstream from the intersection. In the first half of the study three police officers, a marker, a controller, and a recorder, were involved in collecting data at these locations. The marker, in civilian clothing, stood at the premeasured distance from the intersection about two meters from the roadway where he could observe traffic flow. His job was to select a vehicle which met the free flow criteria. When the subject's front bumper was in line with the marker's position, he signalled with the flashlight.

The controller, also in civilian clothing, was standing at the signal box with his hand on the manual button facing the marker. When signalled by the marker, the controller changed the signal phase from green to yellow. The recorder, in police uniform, was located approx 100 meters downstream from the intersection in an unmarked police vehicle, with a clear, unobtructed view of the intersection. When the subject cleared the intersection, the recorder stepped onto the road and signalled the driver to pull over. The driver was then debriefed and questioned, according to a script as to why he/she reacted to the light in the manner he/she did (stop/not stop). Other information pertaining to the driver and the vehicle was obtained from the driver's licence and vehicle registration.

The recorder also measured the subject's speed using the radar device. An initial speed reading was obtained when the subject was approximately 30-50 meters upstream from the marker. Any vehicle exceeding the speed limit by more than 5 km/h prior to reaching the marker's position was eliminated from the study. The radar was also used to determine what reaction the vehicle had to the onset of the yellow light, particularly whether or not it accelerated when travelling through the yellow phase. Ten subjects were measured at each distance for a total of 40 per location.

For the first part of the study drivers who did stop for the light were interviewed and received a 'Good Driving Summons' which is a written record of the fact that they were stopped for obeying all of the traffic laws. This was part of a saftey campaign being sponsored by the Calgary Police Service and CHQR radio. After 20 drivers had been interviewed this part of the procedure was omitted as it was time consuming and provided little further information. The reply was invariably that the driver saw the light and had no problem stopping. Driver and vehicle demographic data were recorded just through observation (driver age was estimated). In the last half of the study a manpower shortage reduced the study team to two constables. The duties of the marker and the recorder were collapsed, with the unmarked vehicle now sitting upstream from the light, in line with the distance marker. A radar reading was still obtained. In this mode the only thing that was not performed was the stopping and debriefing of the driver.

RESULTS

A Chi Square analysis comparing stopping distance and stopping behaviour indicated a significant difference between the stopping distances ($X^2 = 57.49$, df=3, $p<.01$). An analysis on the locations themselves indicated that there was no significant difference between the locations ($X^2 = 4.6$, df=3, $p>.01$). Table 15 shows a breakdown of the data collected. By calculating the intercept of the best fitting straight lines between those drivers stopping and those who did not, the median stopping distance from an intersection was found to be approximately 59 meters.

DISCUSSION

Although a vehicle travelling 50 km/h can come to a panic stop in in 23.6 meters (assuming .75 second reaction time, dry pavement, and a well maintained vehicle) and 34 meters for a more controlled stop (Alberta Driver's Manual), the city generally allows for 55 meters by providing a four-second yellow light, which is now standard in Calgary. The results of this study indicate that, left to their own judgement, 50% of drivers would take over 59 meters or 4.2 seconds

Table 15

Summary of vehicles stopping for
a yellow traffic light by location

Location	Distance									
	41 m		55 m		69 m		83 m		Total	
	S	NS	S	NS	S	NS	S	NS	S	NS
Elbow	0	10	6	4	9	1	10	0	25	15
Heritage	0	10	6	4	4	6	8	2	18	22
24 Ave	1	9	7	3	8	2	10	0	26	14
Richmond	4	6	5	5	8	2	9	1	26	14
Total	5	35	24	16	29	11	37	3	95	65

S = number of vehicles that stopped
NS= number of vehicles that did not stop

before stopping. This suggests that most Calgarians have little regard for yellow lights. This is supported by the replies of those drivers questioned after failing to stop for the light. At the 3-4 second interval drivers said that they either were not paying enough attention to the light or simply didn't think they had to stop. Some mentioned that they felt they were going too fast to stop safely (although they were travelling at the speed limit). At the 5-6 second interval, violators said that they were in a hurry and didn't want to stop. One driver accelerated from 50 km/h to 75 km/h in order to avoid stopping for the yellow light.

One of the applications of this study is to evaluate enforcement or some other program to cause drivers to stop for yellow lights. If the program is successful, then the median stopping distance that drivers will voluntarily accept will decrease. There will also be a decrease in the number of vehicles in the 4-6 second category. If the program attempts to increase attentiveness as well, then there may also be a substantial decrease in the number of people driving through the yellow phase beyond the 3-second interval.

Although this study did not show a significant difference between the locations selected, it is likely that some intersections will have different risk factors than others, particularly if there are differences in the posted approach speed. The type of traffic which utilizes the roadways may also be a factor, as is the proximity of the light to other traffic signals. If traffic lights are close together, as they are in downtown, the phase of one may affect behaviour at another.

A short pilot study looked at this possibility at the intersection of 7th Avenue and 2nd Street S.E. where there was a continuing problem of vehicles running yellow and red lights. If vehicles travelled through the yellow at 7th Avenue they would be rewarded by a green light at 6th Avenue. This seemed to reward drivers who violated the lights. For a three week period, the lights at 6th Avenue were changed so that they turned yellow prior to the lights at 7th Avenue. This resulted in a decrease in the number of vehicles which failed to stop for the lights at 7th Avenue. A more carefully controlled study will have to be done to validate this phenomenon, but it seems logical that violation behaviour can be reduced if the reward for that behaviour is also reduced.

As mentioned, the speed of vehicles approaching the light may also affect the stopping behaviour of drivers. It is posited that drivers at faster speeds will be less likely to stop in the same time frame because it requires more braking and then more time and acceleration to get back up to their previous speed. This would have to be tested. It was not done in this study because the faster roads in Calgary had just been converted to computer controlled signal operation and the manual overrides had been temporarily disconnected.

Additional research concentrating more closely around the 4-second interval may yield a better indicator of the exact median distance that drivers will voluntarily stop. Research should also be done to determine how easily drivers are influenced by the actions of traffic around them when committing infractions. A study similar to the present one could be conducted but including a confederate who, driving a vehicle, would take a position beside, behind, or in front of, the subject vehicle and observe the subject's behaviour. In some instances the confederate can stop for the light and in others, drive through. The product of this type of research is an increased knowledge of the offence behaviour that we are trying to modify or control.

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Calgary's traffic safety problem remains at a serious level despite continued and expensive efforts of several agencies, including the Calgary Police Service. The principal theory used by these agencies is a risk-taking model which the author believes to be inadequate in explaining the entire problem. It is posited that the safety problem had not been sufficiently diagnosed and that the approach being used is only affecting an undetermined portion of the safety problem. It was further posited that inattention is having a much greater impact on the traffic safety problem than is presently being recognized and that this impact is not being considered when developing countermeasures.

The traffic safety literature demonstrates that problem definition frequently dictates which solutions will be attempted. Since most agencies involved with traffic safety have defined the problem as behavioural, they have concentrated on programs such as enforcement, education, legislation, and increased use of traffic control devices. There has also been a tendency for researchers in the area to concentrate on driver risk taking in developing comprehensive theories to explain the problem.

The most notable theoretical approach was Wilde's Theory of Risk Homoeostasis. Wilde and others have determined that road users have accepted a certain level of subjective risk while using the road system and that their actions are determined by the degree to which the perceived objective risk equates with the internal level of subjective risk. Wilde has developed a mathematical equation explaining this relationship which, unfortunately, does not hold up well under close scrutiny. This model is now receiving more criticism than support. Other models, including Evans' Human Behaviour Feedback Model, tend to be more descriptive of the traffic safety problem than predictive. This limits their usefulness. The tendency to group all traffic behaviour together instead of focusing on separate, and perhaps unique, individual behaviours may be responsible for the failure to develop a comprehensive, predictive theory of traffic safety.

Speeding is probably the most common traffic offence committed. It is also the best enforced. Over 15,000 summonses are issued annually in Calgary for this offence. This may be due to the ease of detection or due to the prevalence of the offence. Although the majority of speeding incidents do not result in a collision, there is no denying that speed is positively correlated with injury severity. An increase in speed also decreases the time available for evasive action and increases braking distances, making collisions more likely. An important objective of a traffic safety program is, therefore, to ensure that drivers operate at speeds that maximize safety.

There is ample evidence to support the effects that enforcement has on speeding behaviour. However, there is very little information on whether enforcement increases driver attentiveness. There is also little work done on the deterrence effect of enforcement on those drivers that commit the offence through inattention rather than risk-taking. The research performed to locate the residual and halo effects of enforcement also indicate the limitations of enforcement. The principal limitation may be that outlined by Shinar (1978) when he stated that most enforcment agencies are concerned with tactics to obtain immediate objectives instead of with strategies to obtain long-term goals.

Shinar also indicated that for enforcement programs to be effective they must be highly visible, appear threatening, have some measure of uncertainty, and be widely publicized. His conclusion was that enforcement need only follow a reinforcment schedule, as determined by operant conditioning theory, to be successful. This overly simplistic approach to traffic safety is not without its supporters. The large infraction rates and abundance of collisions are ample evidence, however, that road users make much poorer conditioning subjects than do pigeons.

The results of experiments 1 and 2 give support to the idea that inattention is responsible for a significant amount of traffic violations. In the first case there was a significant decrease in speeding brought about by an arousal-inducing stimulus. It must be noted, however, that the impact of this stimulus declined rapidly as drivers became accustomed to it. This type of stimulus should work more consistently where there is strong social pressure on drivers to comply with the posted speed limits, since infractions would be almost totally the result of inattention rather than deliberate actions.

The manipulation of feedback in experiment 2 also appears to have increased overall attention levels. The sign had the added dimension of a low-level threat of enforcement and an implied peer pressure. This combination was highly effective. Research done by VanHouten et.al. (1982) indicates that the effectiveness can be increased by strengthening the connection between the sign and police enforcement. Unlike the diminishing lines, however, this type of stimulus is not passive. The sign must be noticed and read before it can be effective. It would not be effective on those road users that were totally oblivious to their surroundings. This approach would also be less effective in congested areas where there is a great deal of visual information to be processed and the sign could be easily missed.

Each of the above strategies has certain qualities that make one preferable over another in certain situations. The diminishing lines reinforce a speed reduction zone through a highly visual stimulus which is difficult to miss or ignore. This draws the road user's attention to his/her immediate surroundings, which in turn should induce a desire to reduce speed. The stimulus is, therefore, most effective in those areas where there is a high degree of voluntary compliance, but the speed zone is subtly indicated or there are many distractions. By reinforcing the speed reduction requirements voluntary compliance can be optimized in critical areas, such as playgrounds or school zones. Overuse of this strategy could seriously undermine its effectiveness, however.

Public posting works in those areas where the social pressure on voluntary compliance is not as great. In fact, one of the goals of this approach is to instill an artificial sense of peer pressure through a displayed high percentage of "drivers not speeding yesterday". Since voluntary compliance may not exist, this strategy also indicates that vehicle speed is being monitored, possibly by law enforcement agencies. VanHouten et.al. (1982) discovered that the addition of a police crest on the sign did not increase the sign's effectiveness. This could mean that the crest is superfluous and the police connection is already assumed by road users, or that the monitoring agency is less important than the monitoring itself.

Where the diminishing lines draw attention to a driver's immediate surroundings and present speed through an illusion of acceleration, public posting draws attention explicitly to vehicle speed and posted speed limits. This makes public posting more applicable in those locations that do not automatically induce speed reduction. Although both tactics have similar goals, they will be effective in different areas. The Deerfoot Trail off ramp used in experiment 1 would likely have been a more suitable site for the public posting sign than the diminishing lines. This is evidenced by the rapid decay of the speed reduction effect at this site.

Enforcement would work in conjuction with both of the above tactics. There will still be a group of road users that will speed deliberately, for a variety of reasons, no matter what the location. Obviously they are accruing some benefit from the activity which is worth the risk of detection and/or collision. A higher level of enforcement may balance out this benefit and reduce the incidence of the behaviour. Since enforcement personnel are very expensive and in short supply, this strategy is much more effective if it can be targetted to those areas where there is a specific need and to those individuals who will benefit most by it. By placing the appropriate attention-inducing stimulus at a problem area, those road users who are inattentive will be corrected and those who commit the offence anyway are likely deliberate offenders who may benefit from enforcement.

Speeding is not, however, the only traffic offence of importance. As mentioned previously, traffic light offences have a much higher probability of serious collision than any other offence. There is a definite need for more research into driver behaviour at these locations. Experiment 3 revealed fairly high offence rates at selected intersections in Calgary. Although enforcement had an impact, the effects were highly variable and ephemeral. This study also revealed one major drawback in this type of approach to studying traffic light behaviour. There is a short 'opportunity window' through which an offence can be committed at any given intersection, depending on distance from the light and speed at the time the light changes color. There is no evidence that this window remains constant throughout an experiment.

Experiment 4 attempts to control for these difficulties by developing a measurable dependent variable of driver response to traffic lights. From these responses an attitude about stopping for traffic lights can be derived. Once this measure is established, researchers could then evaluate the impact of countermeasures directly on driver behaviour and not have to imply it from offence and collision rates. This experiment showed a surprisingly high lack of regard for yellow traffic lights. Over half of the sample tested required a yellow phase longer than the four seconds presently being supplied before they would stop voluntarily.

Studies in enforcement tend to concentrate on the risk-taking theories. If they fail to obtain a significant result then the author usually claims that the wrong type of enforcement was used, not that the theory is questionable. Some have argued that enforcement can be effective in increasing attention levels by treating inattention like any other behaviour. Drivers will pay more attention if they know that they will be penalized for inattention. There will have to be a great deal more work into the psychological mechanisms of inattention before this view can be supported or dismissed. Generally, however, behaviour modification techniques are more effective on errors of commission than on errors of omission which more accurately describes mistakes made through inattention.

RECOMMENDATIONS

1. That priority be given to the development of a comprehensive classification system that discriminates each individual occurrence of a traffic safety event, both collision and near collision.

To understand the traffic safety problem it will be necessary for researchers to redefine what they are looking for. We are presently looking at this problem as if it were one phenomenon with specific behavioural patterns regardless of the type of offence committed. A more likely approach is that traffic safety is an order or family within a much larger kingdom or phylum of safety problems. There will be, therefore, very specific and unique genus and species of traffic problems within this larger context.

The basic structure of this taxomony should not be too difficult, given the present state of traffic and vehicle engineering, and our knowledge of the human information processing and reaction capabilities. Since the physical design of the roadway will be the most static, it should be considered first. This will include such things as road surface, plane, slope, radius of curve, lane width, lane markings, ambient lighting, and traffic control devices present. Each of these will have to be considered under a variety of weather and ambient light conditions.

The vehicle would likely be considered next, since its pre-impact condition can be determined accurately in most collisions. This would cover such items as speed, brake condition, windshield visibility, vehicle mass, make and model, condition and type of tires, its age, state of repair, and other relevant information.

The human condition would be the most variable and the most difficult to obtain completely. Age, sex, mass, positioning in vehicle, and nature of injuries will be relatively straight-forward. Sensory impairments, level of fatigue, presence of drugs (including alcohol), driving experience, mental preoccupations, distractions, general condition of health and other important factors may not be readily available.

The major challenge of this taxomony will be to classify specific events across all three factors. Each condition will likely have more than one factor present. It will be necessary to understand how various items combine to yield a unique outcome. In order to do this researchers will have to analyze both traffic mishaps and acceptable driving and then compare them to determine their differences which lead to collisions. This will be a demanding task which may not even be possible, given the incredible variety of conditions and combinations. It will probably be necessary to make generalizations and assumptions before a rough taxomony can be available.

Although work on specific areas within this taxomony can be done in any transportation network, any attempt to tie it together into a comprehensive package should be done first in relatively small, controlled areas, such as a small or mid-sized town. This way variables can slowly be added to the model as it is applied to different and larger areas.

2. That attempts to improve the traffic safety problem at any given location be tailored to the specific conditions and requirements of that location.

Until the above mentioned taxomony is developed it will be necessary to deal with specific problems at specific locations according to their individual characteristics. These problems will not be static, however, since the individual motivations and behaviours that give rise to them will be changing constantly. Each location targetted for a traffic safety countermeasure will have to be analyzed in detail prior to implementation. It will be necessary to know exactly what the problem is, and why a specific countermeasure is being contemplated. It will also be necessary to understand why road users operate at that location. Unlike most behaviours, drivers and other road users rarely use the transportation network for intrinsic rewards but rather to reach some destination, at a specific time, to perform some other behaviour. Pedestrians are not going to wait for a traffic light if it means that they will miss their bus or train. Drivers are less likely to stop at traffic lights if they are not synchronized with the ones before and after.

3. Determine the minimum attentional, sensory and motor requirements of any given problem location and create environmental cues that raise these factors to meet this minimum.

By working on a taxomony listed above, researchers will be able to ascertain the minimum sensory and motor abilities required for any given location with various types of vehicles. If a certain level of attention is required to make a specific maneuver safely then the environment should provide cues to induce the appropriate level of attention. If specific vehicle factors reduce this performance below an acceptable level then steps should be taken to remove those factors through more stringent vehicle checks and regulations.

A valuable guideline would be the proposals of Haddon and Baker (1981) for determining effective countermeasures. First, emphasis should be placed on those measures that will most effectively reduce injury losses without undue focus on the behavioural factors that give rise to the problem. Safety guards on power tools will protect people even when the tools are used incorrectly. Injuries are reduced without attempting to eliminate human error. Secondly, the strategy should be mixed across the pre-event, event, and post-event phases of the collision problem. In this way efforts are not only made to prevent the occurrence of the event but also to minimize the consequences. Third, preference should be given to passive measures that are not dependent on a great amount of individual action and responsibility in order to work. Finally, consideration must be given to cost and effectiveness. The efficacy of each strategy must be carefully evaluated if using limited resources. Problems must be priorized with regard to frequency and severity. Resources should be allocated to where they will be most effective.

4. Keep current traffic theories simple and specific.

Comprehensive theories of traffic behaviour will unlikely succeed until the above taxomony can be developed. The classification system will give the necessary framework in which the theory can operate. The road user does not exist outside of the road system and therefore cannot be understood unless placed into context. Until that time we must be satisfied with limiting our theories to more specific situations. By studying driver behaviour at traffic control signals we should be able to develop a workable comprehensive theory for that specific condition. It may or may not be applicable to a theory of stop sign behaviour. Perhaps when we can understand each part of the traffic safety problem, we will be able to explain the whole problem.

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