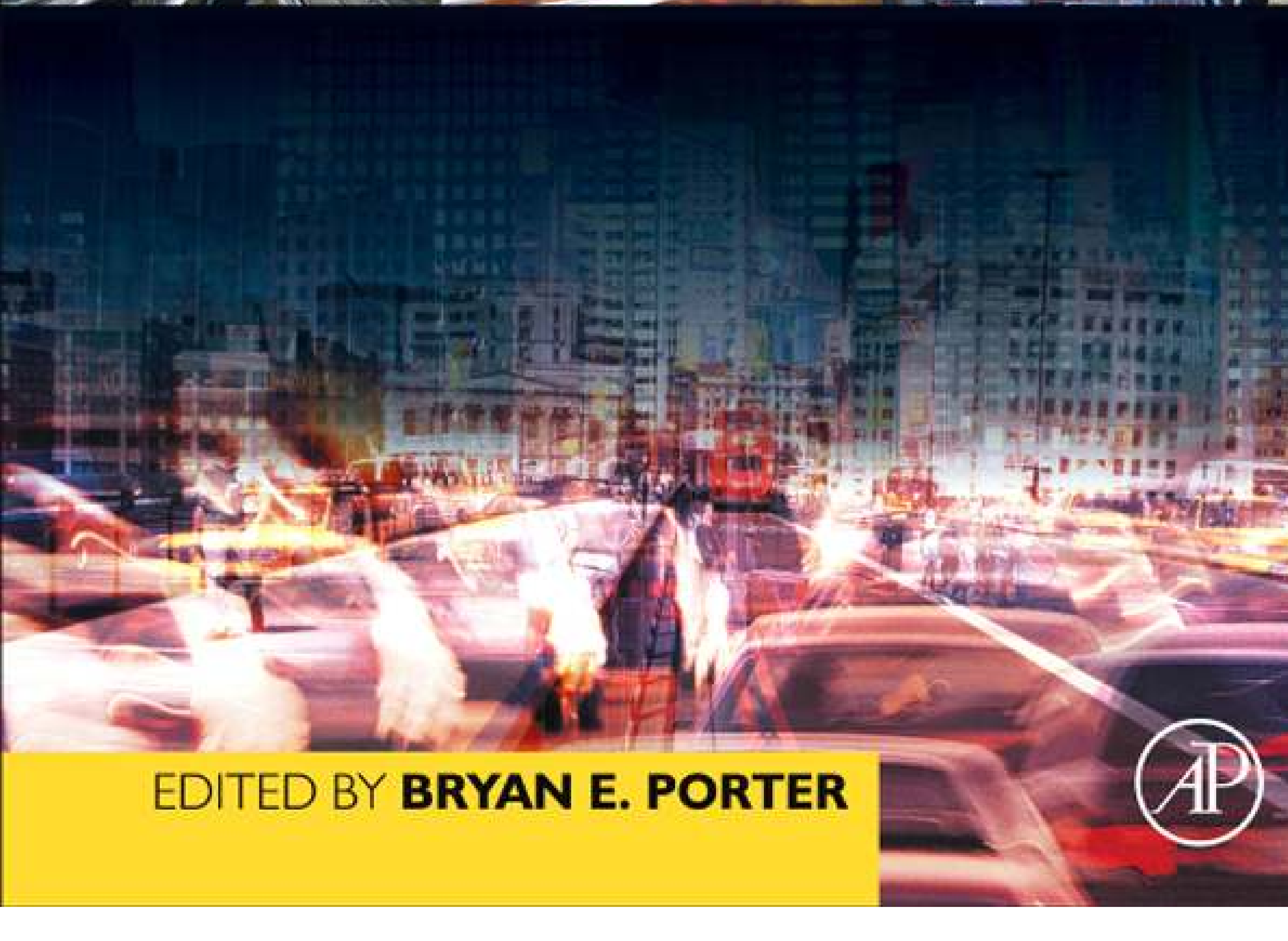
HANDBOOK OF

TRAFFIC PSYCHOLOGY



EDITED BY **BRYAN E. PORTER**

Handbook of Traffic Psychology

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Handbook of Traffic Psychology

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Contents

Preface

In compiling the *Handbook*, I had a vision to place into one work the latest research findings and future questions to be pursued in the field. I wanted the work to reach multiple audiences, including advanced undergraduates learning about applications and methods, graduate students needing the latest reviews and suggestions for research questions, and scholars in the field who benefit from one resource representing the field at-large for ease of reference and background. The final result, I believe, completes the true meaning of "handbook"—a "how to" resource to know, and do work in, the field. It can even be adopted as a textbook for courses in traffic psychology.

The book's chapters are organized into six main sections: (1) Theories, Concepts, and Methods; (2) Key Variables to Understand in Traffic Psychology; (3) Key Problem Behaviors; (4) Vulnerable and Problem Road Users; (5) Major Countermeasures to Reduce Risk; and (6) Interdisciplinary Issues. Each chapter is a stand-alone resource for readers who want to start with a particular issue or topic. The chapters within each section also have different purposes and, at times, will attract different audiences whose needs vary depending on experience in traffic psychology. The material within is global, coming as it does from contributors representing 12 countries on five continents. There is also a breadth of interdisciplinary perspective, with experts from psychology, engineering, medicine, political science, and public health.

The first section, Theories, Concepts, and Methods, gives readers an overview of traffic psychology as a field (Groeger), theoretical contributions (Fuller), and "how to" chapters to practice common methods. Case–controls (Híjar, Pérez-Nuñez, and Inclán-Valadez), self-report (Lajunen and Özkan), direct observation (Eby), in-vehicle instrumentation (Klauer, Perez, and McCafferty), simulation (Carsten and Jamson), and crash data set methods (Kweon) are discussed. New students in traffic psychology, or experienced scholars wishing to consider different methods, will particularly benefit.

In the second section, Key Variables, a wide range of variables are explored that provide—literally—the "set" of those thought to be among the most important to understand. Authors explore neuroscience contributions to driving (Glendon for young drivers; Schultheis and Manning for older drivers), which are becoming very important to the field and its future potential. Visual search patterns (Crundall and Underwood), social, personality, and affect (Hennessy), and mental health impacts (Taylor) are explored. Finally, the person, environment, and culture (Özkan and Lajunen) and human factors (Oppenheim and Shinar) impacts are reviewed. In these chapters, readers can review the latest information and research questions from within a person through to that person's interactions with the larger social system.

The third section will be very popular with readers interested in particular behaviors. Here, chapters provide what is the latest known—and unknown—about major problem behaviors leading to crashes, injuries, and fatalities. These behaviors are critical for traffic safety at-large, not just traffic psychology. These are safety-restraint use (Vivoda and Eby), impaired driving (Dunaway, Will, and Sabo), speeding (Berry, Johnson, and Porter), running traffic controls (Retting), distracted driving (Regan and Hallett), and fatigued driving (May).

Vulnerable road users are the focus of the fourth section. Traffic psychology and related fields have a significant interest in reducing harm to subgroups of people who are disproportionately harmed on the roadways or who need particular protections that they cannot provide themselves. The field also focuses on those subgroups that disproportionally create roadway problems. This section's chapters review young children and "tweens" (Will), young drivers (Huang and Winston), older drivers (Freund and Smith), pedestrians (Van Houten), bicyclists (Walker), motorcyclists (Houston), and professional drivers (Rosenbloom).

Traffic psychologists and their colleagues are often called upon to assist in the development and evaluation of countermeasures to reduce roadway risks. The fifth section reviews major countermeasures that have received the most attention to date. Specifically, driver education and training (Keskinen and Hernetkoski), persuasion and motivational messaging (Anderson), and enforcement (Porter) are discussed. Readers in the field, or those practicing in general transportation sciences and policy, will find these chapters useful in their discussions about what questions and countermeasures may or may not be appropriate to address their needs.

Finally, the sixth section provides interdisciplinary perspectives. Readers will find how traffic psychology intersects with public health (Sleet, Dellinger, and Naumann) and public policy (Elvik). Environmental protection by reducing personal vehicle use in favor of public transport or other mode choices has a growing research base (Stradling). Also, traffic psychology's role to assist worldwide injury prevention, with Africa as an important and critical example, is outlined (Peltzer).

Given the ambitious nature of the work, I thank my family, Debbie, Amanda, and Sadie, and my students, whose patience and support I much appreciate. Old Dominion University's support has also been substantial to my work on the *Handbook*, including a semester's research leave to help organize the project. I thank my publisher at Elsevier, Nikki Levy, for her support of this work, and Barbara Makinster, who was my development editor. Finally, I thank my colleagues who kindly offered advice on early drafts of the handbook material: David W. Eby, Ian Glendon, Raphael Huguenin, Geoffrey Underwood, and Kelli England Will.

I am delighted to share the *Handbook*—finally after so much planning and execution—with readers interested in traffic psychology. I am excited to share how my field can make important contributions to reducing crashes, injuries, and fatalities on our roadways. I am honored to provide a forum for my colleagues to share their tremendous experience with those wanting to know who we are as a discipline. I am also proud to provide this resource to the field to celebrate its accomplishments. On behalf of the *Handbook*'s authors, I hope you both enjoy the book and find it useful to your own pursuits in our exciting discipline.

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Part I

Theories, Concepts, and Methods

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Chapter 1

How Many E's in Road Safety?

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1. INTRODUCTION

I was introduced to driver behavior research by Ivan Brown, with whom I went to work at the Medical Research Council's Applied Psychology Unit in 1985. Ivan's knowledge of the field was voluminous, and his proselytizing on behalf of a psychological dimension to road safety was both tireless and remarkably successful in shaping decades of research in the area in the United Kingdom. If Ivan shaped the UK agenda, Talib Rothengatter (d. 2009), with whom I first began to collaborate in 1987 as part of the remarkably foresighted European Union-funded GIDS project (Michon, 1993), gave form and substance to the behavioral aspects of traffic psychology throughout Europe and beyond. Both would have written this overview chapter far better than I can hope to do.

Although I was, and remain, more interested in the cognitive underpinnings of complex skilled activity, road safety was much more central to Ivan's concerns. He was the first person I encountered who invoked the "three E's" mantra of road safety. It is only recently that I found reference to what is, I believe, the original coining of the phrase "education, enforcement, engineering." According to Damon (1958), Julien H. Harvey, who was then director of the Kansas City Safety Council, gave a presentation in Topeka in 1923 during which he presented a drawing of a triangle with sides labeled "Education," "Enforcement," and "Engineering." Since then, the three E's have dominated perspectives on road safety, with occasional forays into the literature by safety experts advocating increasing the number of E's in road safety. I, too, am going to travel this path in an attempt to overview what I consider some of the most important contributions to the literature in recent years.

2. EDUCATION

One of the virtues of the three E's is the succinct summary they offer of what remain the primary parameters of safety. However, in each case, drawing the remit of each "E" narrowly limits not only the scope but also the extent of the potential to contribute to safety. This is demonstrably so with respect to "education."

Education has come to mean the transmission of an established body of knowledge and skills to those who lack these. In the road safety context, it has less to do with the developing of individual potential, implicated in wider use of the term "education," and typically refers to "driver education" and "public education."

Driver education is a term used more widely in North America to cover the preparation of intending drivers for independent driving. It comprises, depending on the jurisdiction, classroom or electronic dissemination of the declarative knowledge base on which driving relies, as well as what is typically referred to as "driver training" (i.e., practical instruction on the operations the driver is required to perform when driving, including the rules that pertain to vehicle operation (Lonero, 2008)). Despite the evident face validity of driver education, the evidence of a direct safety benefit from driver education is scant and equivocal, as a succession of reviews during the past few decades have shown (Brown, Groeger, & Biehl, 1987; Christie, 2001; Ker et al., 2005; Mayhew & Simpson, 2002; Roberts & Kwan, 2001). Evidence with regard to the effectiveness of the skill and declarative knowledge components of driver education is, to some extent, more compelling. For example, there is very good evidence that the driving performance of drivers improves as they gain behind-the-wheel experience with professional driving instructors or accompanying adults (Groeger, 2000; Groeger & Clegg, 2007; Hall & West, 1996). However, there is surprisingly little evidence that the classroom or individual education leads to an increase in knowledge about, and attitudes toward, driving. One study showed that those who were pseudo-randomly assigned to classroom or individual CD-ROM- or Internet-supported study performed similarly on a post-course test of driving-related knowledge (Masten & Chapman, 2004). Unfortunately, the study did not include a pre-course assessment of driving knowledge, and thus the comparability of groups before undertaking courses and the relative improvement in knowledge of driving by virtue of course participation are

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unclear. This suggests that the classroom setting per se does not lead to better outcomes than home study, although the educational value overall is difficult to ascertain. Some studies, which are considered later in relation to exposure, are more encouraging with regard to the contribution of driver education to safety.

Mass media campaigns are also a means by which education might make a contribution to road safety. In discussing their effectiveness, I separate campaigns that seek to change behavior by emphasizing that the unwanted behavior is antisocial, or where there are safety-related consequences of some unwanted behavior, from campaigns that implicate enforcement. Two related meta-analyses of the effects of carefully conducted, substantial, well-controlled media campaigns on alcohol-related accidents (e.g., single-vehicle nighttime crashes) or blood alcohol content levels reveal impressively large reductions in alcohol-involved driving of approximating 13% (Elder et al., 2004; Tay, 2005a). Although impressive, the fact that no more than approximately a dozen studies, worldwide, over several decades met the rigorous standards for inclusion in these meta-analyses is very revealing of the dearth of peer-reviewed studies that demonstrate convincing reductions on relevant outcome measures.

Differences between the effectiveness of campaigns against speeding or drunk driving (Tay, 2005b) both show the inherent complexity of evaluating public education campaigns and emphasize the very important point that even carefully constructed and targeted campaigns may not be equally effective as a means of reducing all unsafe/illegal behaviors, regardless of what these are. Tay's study also serves to emphasize the importance of message content, in that different types of unsafe/illegal behaviors may not equally support "response efficacy" (i.e., provide useful and effective avoidance strategies). The importance of this and other aspects of message content, delivery, pretesting, as well as audience effects and target offenses, has been more formally investigated in a number of other studies. These experimental studies typically use behavioral intentions, rather than measured change in specified actual behaviors, as outcome measures, but they have allowed investigation of the subtle interplay between the threat implied in campaign messages and consequent fear induced and the likely acceptance or rejection of the message among various groups (Cauberghe, De Pelsmacker, Janssens, & Dens, 2009; Lewis, Watson, & Tay, 2007; Lewis, Watson, & White, 2008, 2010). These and other studies have considerable potential to shape message content and delivery, and they provide a coherent account of how and why messages may have the potential to be effective. However, quantification of the actual safety benefits of these and other variables will be a considerable challenge, just as it has been for driver training.

It would be remiss not to acknowledge a final sense in which education can make a contribution to road safety. Many who are engaged in this area have benefited from, and seek to pass on, the expertise and experience of others. As such, those of us in educational roles have the ultimate responsibility for maintaining and enhancing the knowledge base of current theory, methods, and research findings available to policymakers, other safety professionals, and society at large.

3. ENFORCEMENT

Few studies demonstrate the centrality of enforcement to road safety as well as that by Tay (2005b), in which it was shown that the number of breath tests performed per month and the percentage of drivers arrested were associated with a statistically significant reduction in the number of serious crashes per month.

Enforcement is likely to be by far the most important determinant of the likelihood of apprehension for a criminal act, and as such it is critical to deterrence. Thus, for example, classical deterrence theory proposed that criminal acts are less likely to be committed where the certainty of punishment is high and the punishment is both severe and swift (Taxman & Piquero, 1998). Classical deterrence theory emphasizes the importance of direct punishment of the individual. In doing so, classical deterrence theory neglects the potential to increase further offending of offenders' experience of avoiding punishment, as well as their more vicarious experience of both punishment and punishment avoidance (Stafford & Warr, 1993). Piquero and Paternoster (1998) provide empirical support for this reconceptualization of classical deterrence theory, showing that expressed intentions to drink and drive were affected by personal and vicarious experiences as well as by both punishment and punishment avoidance. Furthermore, very strong deterrent effects were observed where the certainty of punishment for the respondent was high. Interestingly, Piquero and Paternoster also show that "moral beliefs that prohibit drunk driving are an effective source of inhibition" (p. 3), and impulsivity among individuals is associated with whether vicarious experience of punishment and punishment avoidance influences offending (Piquero & Pogarsky, 2002). Watling, Palk, Freeman, and Davey (2010) attempted to extend this analysis to "drug" rather than "drunk" driving. They showed that punishment avoidance and vicarious punishment avoidance were predictors of the propensity to drug drive in the future but note that knowing of others apprehended for drug driving was not a sufficient deterrent. It may be that particular types or patterns of drug use are more prevalent among individuals high in impulsivity, and if so, increased vicarious knowledge of punishment through publicity or media reports of detection might not be effective for specific driving-under-influence offenses (in addition to the difficulty of using media appropriate for such offenders).

In part because of the influence of vicarious knowledge of detection and punishment on deterrence, publicity campaigns enhance the effect of rigorous enforcement. Miller, Blewden, and Zhang (2004), during the introduction of a zero alcohol tolerance regime for drivers younger than age 20 years, investigated the effects of compulsory roadside breath testing (CBT), CBT twinned with a media campaign, and a subsequent period of greater police presence during CBT (i.e., "booze buses"). They reported a reduction in expected nighttime crashes of 22.1%, with a further reduction of 13.9% due to enhanced media, and that booze buses yielded a further 27.4% reduction where implemented. This almost halving of expected nighttime accidents persisted for several years beyond the life of the intervention.

Whereas Miller and colleagues (2004) showed that increasing the apparent seriousness with which offenses are treated by enforcement agencies serves to increase deterrence, diminishing the seriousness of offenses appears to have the opposite effect and has a more general effect on safety. McCarthy (1993) reported that an increase in rural interstate speed limits significantly increased overall the incidence of alcohol-related accidents, and that alcohol-related accidents became more prevalent in lower speed environments. Blais and Dupont (2005) emphasized the pervasiveness of safety effects resulting from strict police enforcement. Reviewing the international literature on enforcement programs focused on a broad range of offenses (including random breath testing, sobriety checkpoints, random road watch, photo radar, mixed programs, and red light cameras), they concluded that interventions resulted in an average decrease, ranging between 23 and 31%, of injury accidents. On the other hand, the consequences of lax enforcement are demonstrated in a case-crossover study of traffic law enforcement and risk of death from motor vehicle crashes (Redelmeier, Tibshirani, & Evans, 2003). These authors showed that there was a protective effect from recent convictions on individual drivers, such that the risk of a fatal crash in the month after a conviction was approximately 35% lower than that in a comparable month with no conviction for the same driver, and that this protective effect declined rapidly a few months after conviction. This protective benefit was consistent across ages, incidence of previous convictions, and other personal characteristics, and it was greater for speeding violations with penalty points than for speeding violations without points. The authors concluded that enforcement "effectively reduces the frequency of fatal motor vehicle crashes in countries with high rates of motor vehicle use. Inconsistent enforcement, therefore, may contribute to thousands of deaths each year worldwide" (p. 2177).

As technologies have developed, the opportunities for enforcement other than by traditional policing have also increased with automated detection of speeding offenses, red light violations, etc. In addition to the roadside reminders regarding potential violations, and the increase in implied and actual surveillance, the increased likelihood of punishment, and reduced opportunity for punishment avoidance, automated detection systems greatly enhance the potential for deterrence. There is substantial evidence that speed cameras not only reduce speeding but also reduce collisions and speed-related collisions (Pilkington & Kinra, 2005), with a meta-analysis suggesting that "injury crash reductions in the range of 20 to 25% appear to be a reasonable estimate of site-specific safety benefit from conspicuous, fixed-camera, automated speed enforcement programs" (Thomas, Srinivasan, Decina, & Staplin, 2008, p. 117). Retting, Ferguson, and Hakkert (2003) reported, on the basis of a meta-analysis of international studies of red light camera effectiveness, that injury crashes overall were substantially reduced at signalized intersections, particularly right-angle injury crashes, although the incidence of rear-end collisions increased. Other studies suggest that although violations are reduced, the overall safety benefit of red light cameras is at least questionable (Erke, 2009; Wahl et al., 2010).

One of the difficulties for automated enforcement is that some who drive are not licensed to do so. A number of attempts have been made to quantify the number of unlicensed drivers in the United Kingdom during the past decade, and two very different approaches to tackling this difficult problem have yielded remarkably similar estimates. In a survey-based approach, samples of those holding provisional licenses (in the United Kingdom, such drivers must not drive without being accompanied by a qualified driver) were written to and asked, anonymously, whether or not they had driven while unlicensed and the extent of that driving (Knox, Turner, Silcock, Beuret, & Metha, 2003). The proportion of drivers admitting to driving illegally was then weighted by the number of drivers known to hold provisional licenses or who were disqualified by the courts. This approach yielded an estimate of approximately 476,300 unlicensed drivers. On March 31, 2006, the UK police randomly stopped 5793 vehicles and checked whether the drivers held current driving licenses, finding that 1.6% did not. Extrapolated to the UK driving population of approximately 31 million, this gives an estimate of approximately 480,000 unlicensed drivers. Various methodological weaknesses underlie these studies. The survey evidence is based on understandably low response rates (10–20%), despite the anonymity of responding, and gives no indication of the number of those who may be driving who have never held a license. The police random survey, by using the number of licensed drivers to estimate the total number of unlicensed drivers, obviously leads to underestimation. In addition to the problem that unlicensed drivers pose for automated enforcement, there is evidence that unlicensed drivers are between three and nine times more likely to be involved in accidents that result in injury or death (Knox et al., 2003). These risk ratios for the general population are similar to those reported for a Californian sample (DeYoung, Peck, & Helander, 1997), although they are likely to be higher for particular groups of drivers (Blows et al., 2005).

Just as studies of more traditional police-based enforcement demonstrate an enhancing effect of education, in the form of concurrent mass media campaigns, these studies of the effects of automated enforcement emphasize an increasing interaction between the effects of enforcement and engineering. This third element of Harvey's three E's safety mantra is considered next.

4. ENGINEERING

Traditionally, safety benefits from engineering would have been anticipated from improvements to vehicle build quality, reliability, improved braking performance, and the protection offered to vehicle occupants. Others arise from improvements to road design, surface quality, reduced deterioration during adverse conditions (Elvik & Greibe, 2005), safer roadside furniture (Elvik, 1995), less confusing signage, etc.

During the past decade, impressive additional safety benefits have accrued from the improvements to occupant protection. Studies of the safety benefits of child safety seats and booster seats for older/heavier children have shown that compared with restraint by seat belts alone, restraint by belts positioned more correctly by the concomitant use of boosters resulted in 59% fewer injuries to children aged 4−7 years who were involved in motor vehicle crashes (Durbin, Elliott, & Winston, 2003), whereas the U.S. National Highway Traffic Safety Administration (NHTSA) reported that child safety seats are 71% effective in reducing fatalities among infants and 54% effective among toddlers (NHTSA, 2009a, 2009b). Safety has also increased because of a reduction in the number of younger children traveling in the front seats of vehicles (Durbin, Elliot, Arbogast, Anderko, & Winston, 2005); children in rear seats are 50−66% less likely to suffer injury (Arbogast, Kallan, & Durbin, 2009). Air bags, although potentially problematic for children (Durbin, Kallan, et al., 2003), have been shown to reduce fatalities in frontal crashes by 14% when no seat belt is used and by 11% when used in conjunction with a seat belt (Braver, Ferguson, Greene, & Lund, 1997; NHTSA, 2009a, 2009b). Seat belt use is also associated with substantial reductions in mortality following head-on collisions (Crandall, Olson, & Sklar, 2001; Evans, 1986). However, although the reductions are robust, it should be acknowledged that both seat belt use and air bag deployment are associated with what are largely less serious specific injuries that would otherwise have been unlikely to occur (Hutt & Wallis, 2004; Smith & Hall, 2005).

These enhancements to occupant protection have well-established safety benefits and have few, if any, direct implication for the way the driving task is carried out. In contrast, developments in in-vehicle and roadside telematics may have profound consequences for how the driving task is carried out and, in some cases, even what the driving task is. Even the most developed systems are still some way from having real market penetration, including systems that are commercially available, and the majority of the systems envisaged are barely at the stage at which live trials in real traffic are possible. Whereas the vehicle modifications presented previously have clear safety benefits, those that will arise from the advance of telematics rely largely on experts' expectations (Kulmala, 2010). Nevertheless, the anticipated safety benefits, assuming systems are fitted in all European Union vehicles, are impressive. Those with the highest fatality reduction potential are electronic stability control (fatality reduction of approximately 17%), lane keeping support systems (~15% reduction in fatalities), and systems that warn the driver when the speed limit is exceeded and when locations with higher incidences of accidents are being approached (~13%). Other systems considered might induce speed adaptation depending on weather conditions, obstacles, or congestion; warn drivers of imminent collisions and apply brakes if necessary; advise drivers regarding accidents, obstructions, and poor visibility or road conditions in the locale; warn of upcoming red light obligations; or assist the driver at nighttime or during other poor visibility conditions by warning of obstructions beyond the range of headlights.

Assessing the safety impacts of future developments is a profound methodological and theoretical challenge that relies on assumptions about how people will adapt to what might be very dramatic differences in what is required of them as "drivers," the road environments in which they will drive, and the likelihood of other vehicles they may interact with having similar technological enhancements. Although I do not doubt that reliable relative assessments of potential safety benefits can be made, the treating of these estimates as likely to result in absolute casualty reductions is premature, at best.

As I have attempted to show, Harvey's three E's have had, and continue to have, considerable relevance for how we conceptualize potential contributors to road safety. In my view, however, other E's, as reviewed in the following sections, also merit consideration.

5. EXPOSURE

Although it is inherent in the concept of risk that negative outcomes are weighted in some way by some index of the possible outcomes, road safety statistics typically consider injury and fatality as head counts, or head counts weighted by the size of the population, numbers of vehicles, or per unit of distance driven, in order to take into account at least to some extent what the relative opportunities are for collisions to occur. This more detailed consideration of such accident data allows us to identify, for example, that young, inexperienced drivers, relative to other motorists, have more of their accidents during weekends, at night or the early morning, or the accidents are more likely to take place when young drivers are accompanied by several similarly aged passengers rather than when traveling alone or when traveling with one other. Discovering particular patterns of "proneness" can be critical to understanding why such events take place, as well as for designing potential countermeasures. Although in principle this proposition might justify including exposure as an additional E in safety, two examples may make its case particularly compelling.

I have been interested in the links between genetics, cognition, and sleep for many years, but it was only when re-reading some literature on young drivers that a particular—as yet untested—hypothesis regarding the overinvolvement of young drivers in accidents occurred to me (Groeger, 2006). A variation on a particular gene (*period* 3) is associated with people's self-declared preferences for being active in mornings or evenings. When sleep deprived, people with these particular genetic variations are especially poor at performing tasks in the early morning (Groeger et al., 2008). During the school/work week, teenagers report obtaining far less sleep than they would wish (Groeger, Zijlstra, & Dijk, 2004); thus, I hypothesized that teenagers with a particular configuration of the *period* 3 gene may actually be more likely to have accidents in the early morning when they had not slept earlier that night (Groeger, 2006). Epidemiological evidence considered in Groeger (2006) showed that when the numbers of reported trips made by young drivers at particular times of the day are taken into account, teenage drivers are far more likely to be involved in road traffic accidents in the early hours of the morning than are drivers in their early twenties. Without the perspicacity of Sweeney, Giesbrecht, and Bose (2004), who reported both accident and trip frequencies by age and time of day, this very detailed and specific prediction would not have occurred to me. If research currently under way in our laboratory provides support for this hypothesis, we may well have a new and quite distinct way of accounting for at least some of the higher crash involvement of inexperienced drivers.

The notion that there are particular patterns of exposure associated with young, inexperienced drivers' accidents is a major part of the rationale underlying graduated driver licensing (GDL) interventions. Although there are a wide variety of GDLs in operation throughout the world, the underlying principles are the same: Higher risk activities, such as driving at night, with alcohol, and with teenage passengers, are delayed until the driver is older. Evidence that GDL is associated with a substantial casualty reduction has been accumulating during approximately the past decade. Although some have suggested that the effects may arise partly through reduced exposure as a result of decreased or delayed licensing, Masten and Foss's (2010) survival analysis demonstrated that 16-year-old drivers experienced lower first-crash incidence during the first 5 years of unsupervised driving than did those licensed under the previous system, with greater benefits for young male drivers. A meta-analysis of the effects of GDL systems goes further and helps to identify which components of GDL are associated with accident reductions (Vanlaar et al., 2009). In the learner stage, these components include the length of night restriction and driver education. In the intermediate stage, the influential components include driver education, whether night restrictions are lifted (for work purposes), passenger restrictions and whether these are lifted if passengers are family members, and, importantly, whether there is an exit test. Two of these effective components are particularly worthy of comment. First, it is noteworthy that the inclusion of a test prior to reducing restrictions is associated with greater reductions in accident risk. Because youthfulness and inexperience both contribute to overinvolvement in accidents, an intervention that reduces risk exposure solely on the basis of age, as I have speculated elsewhere, will be less effective in reducing accidents (Groeger & Banks, 2007). Second, the meta-analysis by Vanlaar and colleagues presents far more convincing evidence for the safety benefits of driver education than has hitherto been found, and it is striking that these emerge when some of the huge variability in exposure of young, inexperienced drivers is controlled. Although not featured in the studies considered previously, the role of parentally imposed restrictions on driving, through parent–teen agreements, etc., is also likely to contribute substantially to increased safety arising from graduated licensing (Simons-Morton, Ouimet, & Catalano, 2008).

6. EXAMINATION OF COMPETENCE AND FITNESS

Perhaps because of the political and societal issues that testing raises, the potential road safety contribution of driver assessment has been largely ignored. Most discussions of driver education and testing readily concede that the competency standards drivers must demonstrate to gain a driver's license are, at best, rudimentary (Baughan, Sexton, Maycock, Chin, & Quimby, 2005; Lonero, 2008; Mayhew, 2007). Increasing the requirement to demonstrate knowledge of the more theoretical aspects of driving seems unlikely to increase driving ability. In the United Kingdom, for example, the pass rate for the on-road driving test changed little after the introduction of extensive theory testing (Wells, Tong, Sexton, Grayson, & Jones, 2008). Wells et al. performed a thorough analysis of the relationship between demonstrating theoretical knowledge of driving and practical driving competence, which controlled for respondent age as well as hours of tuition and practice. The researchers found that no effect of passing a hazard perception theory test was observed among male or female respondents, even when the analysis was conducted separately for those taking their first, second, third, fourth, etc. driving test. Because it does not appear to improve driving ability, theory testing seems unlikely to have a safety benefit, other than by slightly delaying licensing. Another study, also conducted in the United Kingdom, raises serious questions about the reliability of driving test outcomes. Baughan and Simpson (1999) asked candidates taking the practical on-road driving test to voluntarily undergo a second test within days of their first test. The pass–fail designation was the same for 64% of those re-tested, suggesting that substantial numbers of drivers or examiners were unable to perform their respective roles consistently. These findings suggest that there is considerable scope for improving the reliability and validity of the practical driving test. Repeated, rather than one-off, testing and the introduction of more objective, electronic measurement of driver performance would not only identify those drivers capable of performing more consistently but also probably serve to delay licensing—with a consequent increase in safety. Furthermore, as previously mentioned, incorporating testing within a GDL regime has been shown to increase safety; thus, requiring that drivers are competent to cope with the demands of the circumstances in which they will drive when restrictions are reduced has much to recommend it. In my view, improving our ability to examine drivers' competence is perhaps the least well-explored opportunity for enhancing road safety.

Arguably, our rather unsophisticated approach to assessing driver competence has made it particularly difficult to develop rigorous, reliable, and especially valid assessments of fitness to continue driving among those who, through age or infirmity, are believed to pose a greater safety risk. Epidemiological studies, based on different data sets, indicate that older drivers with heart disease or stroke are more likely to be involved in at-fault traffic accidents (McGwin, Sims, Pulley, & Roseman, 2000). Sagberg (2006), using a different methodology, showed that similar risk factors pertain in Europe, adding that nonmedicated diabetes and depression are also associated with greater crash involvement. Although many jurisdictions require that drivers with such conditions notify the licensing authority and withdraw from driving, evidence suggests that compliance with this requirement is low. McCarron, Loftus, and McCarron (2008) reported that among consecutive hospital referrals, approximately 40% of drivers who suffered a heart attack or minor stroke were driving 1 month after the event. There is thus good evidence to support the suggestion that certain medical conditions are associated with increased involvement in traffic accidents, and that voluntary compliance with advice to cease driving is not adhered to. Given the many factors that are associated with lower crash risk, such as not being young, having driving experience, reduced exposure in terms of distance driven, and the timing and circumstances of trips, simply denying those who suffer from heart disease, untreated diabetes, stroke, etc., does not seem justified or fair. Regrettably, our ability to assess the driving skills and competences associated with greater safety is, at best, limited.

A variety of approaches to this admittedly difficult issue have been adopted, and the relative successes of these approaches have been reported (Hunter et al, 2009; Schultheis, DeLuca, & Chute, 2009). Identifying those who pose greater threats to safety than is acceptable, however, is only one part of this complex, and often tragic, problem. Denying people the right to independent mobility, which the motor car has conferred so lavishly on so many of us, cannot be the end of our involvement with this issue as traffic professionals. Involvement might take several forms: counseling or supporting the former driver and family members in order to enable all concerned to cope with the decision, increasing access to other forms of transport, or developing remedial programs that might offer a reasonable possibility for former drivers to return to driving. The scientific challenge of the latter is substantial due to the limited theoretical understanding and practical progress with regard to improving driver education and training and driver assessment.

7. EMERGENCY RESPONSE

For decades, the widely accepted view among medical professionals was that the prognosis for a seriously injured individual was in part determined by whether the patient reached the hospital within 1 h of the trauma onset. A search for historical sources and empirical support for this notion of a "golden hour" proved fruitless (Brooke Lerner & Moscati, 2001; Newgard et al., 2010). Despite this, there is ample evidence that in the case of life-threatening injuries, delaying treatment until the patient reaches a trauma center increases the likelihood of death (Hoffman, 1976). Studies show that compared to patients treated in the field or first hospital destination, patients whose first treatment is delayed until the trauma center is reached are 3.3 times more likely to die (Gomes et al., 2010). Sampalis, Lavoie, Williams, Mulder, and Kalina (1993) reported that a total prehospital time of more than 60 min was associated with a statistically significant adjusted relative odds of dying (OR = 3.0). Based on an analysis of a sample of more than 1400 traffic accidents on motorways and other roads, Sánchez-Mangas, García-Ferrrer, De Juan, and Arroyo (2010) reported that a 10-min reduction in the typical medical response time of approximately 1 h was associated with an approximately one-third decrease in mortality probability.

The circumstances in which certain types of accidents occur, such as in isolated rural areas or at times of the day or night when the crash site is less likely to be encountered by others who might contact emergency services, can leave those involved at greater risk of death. This is particularly the case for accidents involving younger drivers. Work carried out as part of the development of telematic systems estimated that an automated accident warning system linked to emergency services would reduce motor vehicle fatalities in Finland by 5−10%. In 95% of these cases, the consequence would be injuries requiring further hospital and other treatment, and in the remaining 5% the consequence would be injuries requiring no further treatment at all (Sihvola, Luoma, Schirokoff, Karkola, & Salo, 2009). Until such systems are widely available, and even when they are, in the case of severely injured road users, the rubric of (1) getting to the patient quickly, (2) treating what can be treated on site, and (3) getting the patient to an appropriate trauma treatment center as quickly as possible will remain key to ensuring that severe injuries do not unnecessarily result in death.

8. EVALUATION

The seventh, and perhaps most important, "E" in road safety is evaluation. Throughout the previous discussion of the contributions to safety by education, engineering, enforcement, exposure, emergency response, and examining competence and fitness, I illustrated a range of methods and techniques that are critical to making informed, unbiased assessments of the effectiveness of safety interventions. In doing so, I glossed over very substantial challenges of the methods that road safety researchers have used to evaluate the effectiveness of countermeasures during the past century.

Because safety is the desired outcome of interventions in this area, the "gold standard" for those seeking to evaluate effectiveness is casualty reduction, particularly fatalities. Counting crashes and relating these to some "explanatory" variables is the basis of much evaluation in road safety. These explanatory variables may reflect some purposeful "treatment" (e.g., increased penalties, mandatory driver education, and seat belt use) or some change consequent on other developments in society (e.g., economic activity, migration, and fuel shortages). The statistical challenges arising from crash- or casualty-frequency data are very lucidly described by Lord and Mannering (2010). Because crashes are intrinsically rare events, Poisson distributions are generally assumed. As Lord and Mannering note, the Poisson approach requires that the mean crash frequency and variance in crash frequency will be equal, but these dispersion requirements are frequently violated, resulting in biased efficacy estimates. Such count-data methods require that counts are made with respect to some temporal or spatial context. However, information on variations in the explanatory variables of interest is rarely available at the level of detail required to adequately assess their explanatory power. Lord and Mannering use the example of attempting to model the effects of precipitation on monthly crash data, when in reality it is the distribution of precipitation in far smaller time units that is likely to influence whether or not crashes occur. Temporal and spatial contexts may also be intercorrelated, leading to inaccurate assessments of the explanatory power of other variables. Other problems addressed include the difficulties that arise from correlations between injury severity and crash type, underreporting of certain types of crashes, low mean and sample sizes, omission of other potential explanatory variables, and what Lord and Mannering refer to as "endogenous" variables, where the explanatory variable changes as a function of the dependent variable (e.g., evaluating the effectiveness of ice warning signs in preventing ice-related crashes, where ice warning signs are more likely to be placed at locations at which such accidents have occurred). These problems are intrinsic to the dependent variable in which we have most interest and on which we seek to exert a causal influence. Detecting and inferring causality is, to say the least, problematic.

An insightful paper by Ezra Hauer (2010) considers "causality" in two other approaches to evaluation in road safety: cross-sectional and before−after studies. He demonstrates the difficulty, perhaps even the impossibility, of inferring causality in both cases. Hauer's case is that cross-sectional regression studies, in which crash frequencies are contrasted across sites with different types of intervention, rarely capture, and then poorly account for, what Lord and Mannering (2010) might refer to as the spatial and temporal context and also other circumstantial aspects of individual interventions. By doing so, cross-sectional studies can neither negate nor corroborate each other's findings. Before−after studies, although more closely having the experimental control Hauer advocates as essential for determining causation, yield outcomes in which the efficacy of treatments depends on the particular circumstances of the treatment sites. Thus, the safety effects of replacing a stop sign with a traffic signal will depend on the amount and nature of traffic using the intersection, the number of lanes over which control is sought, the proximity of treated intersections to untreated ones, their relative conspicuity, and a host of other factors.

Without a very large number of treated sites, for which the characteristics of each are carefully recorded, it is impossible to adequately estimate the extent to which any effect observed depends on particular circumstances in which the treatment is realized. Hauer implies that without being able to do so, predicting the effect an intervention will have in a given circumstance is impossible (see also Hauer, 1997).

Hauer (2010) makes a further point that is sometimes neglected when road safety researchers engage in evaluation: Theory in road safety is weak but indispensable. In addition to citing a discussion between the eminent statisticians William G. Cochran and Sir Ronald Fisher in which the latter argued that elaborate theories, in which as many consequences of causal hypotheses are envisioned as possible, were among "the most potent weapons in observational studies" (Cochran, 1965, p. 252), Hauer asserts that "to do applied research without providing a theory is like attempting to build the roof of a house with no foundation" (p. 1130). Hauer's comment testifies to what is in my view the essential step we must make to move from mere description to prediction—the building and testing of theory. Fisher's comment regarding the required elaborateness of theory, and the need to envision as many consequences of a theory as possible, is particularly apposite for road safety. As discussed previously, there are many difficulties in using crash or casualty counts, but alternatives are available to our research generation as to no other. The increasing sophistication of onboard vehicle and roadside monitoring systems, largely developed for nonsafety purposes, affords a broader range of dependent variables for assessing performance than ever before. Such nonintrusively collected data are almost routinely available, potentially from truly representative samples of drivers, and genuinely reflective of what these drivers actually do—not just those whose misfortune it is to crash. Shankar, Jovanis, Aguerde, and Gross (2008) offer a very helpful primer on the use of such naturalistic data in road safety settings. Theories that elaborate the link between these variables downstream to safety and upstream to models of intended and unintended driver behavior can meet the requirements of Fisher's dictum and offer the possibility of more cost-effective, reliable, and extensible evaluation.

Although I have been more critical of this final "E" than of any other, it is probably the most important contributor to future safety. Without evaluation, there would be no measurable contribution to safety of any intervention, no opportunity for researchers to test their predictions concerning how and why certain interventions may be effective, no opportunity for policymakers to implement those interventions most likely to prove effective, and no opportunity for road safety experts to optimize their implementation.

9. CONCLUSION

In this chapter, I considered Harvey's three E's and their contribution to road safety, and I discussed how they remain a very useful way of considering safety interventions, despite the fact that almost a century has passed since they were first proposed. I also identified other potential contributors to safety: exposure, emergency response, examining for competence, and evaluation. I doubt that these additional E's will endure as long as those Harvey identified, nor would I encourage others along this acrostic path. The purpose of exploring this highly influential mnemonic was to acknowledge both the contribution its elements have made and their continuing relevance. Each element, and indeed the offspring of each element, is more complex than the original formulation acknowledges. This methodological and theoretical complexity arises largely from the increasing inter- and intradisciplinarity on which our field, and ultimately "safety," relies.

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Chapter 2

Driver Control Theory

From Task Difficulty Homeostasis to Risk Allostasis

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1. INTRODUCTION

Driving may be described as a control task in an unstable environment created by the driver's motion with respect to a defined track and stationary and moving objects. The task includes requirements for route choice and following, coordination of maneuvers in support of navigational objectives, and ongoing adjustments of steering and speed (Allen, Lumenfeld, & Alexander, 1971). Figure 2.1 shows speed adjustments by a driver on a winding country lane, sampled at 5-s intervals. A fundamental issue in understanding driver behavior is the nature of the control process that produces such variations in speed.

Control theory is predicated on the assumption that driver control actions are dependent on perceptual processes that select information that is compared to some standard or standards. Drivers act to keep resulting discrepancies within acceptable limits in a negative feedback loop as the means of control in their goal-directed behavior (Figure 2.2). Ranney (1994), in his review of the evolution of models of driving behavior, makes a distinction between motivational and cognitive models and by implication includes control theory (e.g., Wilde's risk homeostasis theory; Wilde,1982) within his motivational rubric. However, as can be inferred from the previous description, control theory encompasses both motivational (setting of standard) and cognitive (perceptual process) dimensions and is a characteristic not just of risk homeostasis theory (RHT) but also of zero-risk theory (Summala, 1986), Vaa's (2007) "monitor model," Summala's (2007) "comfort zone model," and the task–capability interface (TCI) model (Fuller, 2000). It is with such models that we have seen the most evolution in recent years. All these models differ, however, in terms of their claims regarding what is the reference standard(s) in the control system. The principal aim of this chapter is to describe developments in how the TCI model conceptualizes these standards. It concludes by exploring whether, in the interests of theoretical parsimony, the different reference standards that have been proposed by Vaa and Summala can be assimilated into the developed TCI model.

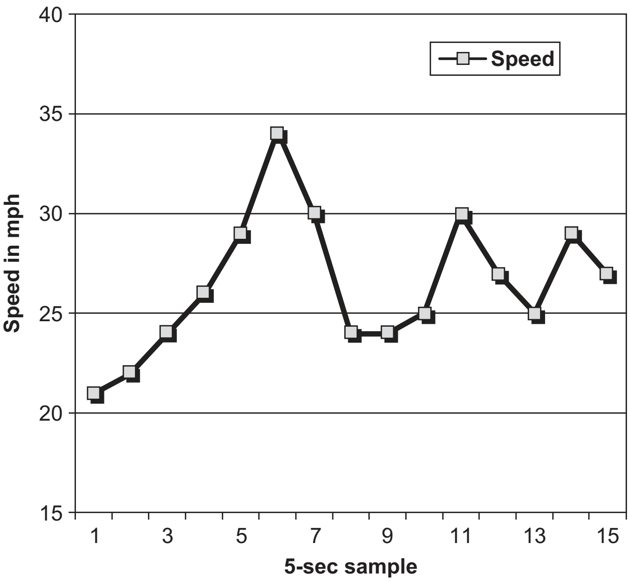

FIGURE 2.1 Variation in speed on a country lane.

2. THE TASK–CAPABILITY INTERFACE MODEL

The TCI model is an attempt to understand what motivates driver decision making, with a particular emphasis on implications for performance safety. It starts from a recognition that driver perceptual processes and control actions both have rate limitations. Thus, the driver needs to continuously create and maintain conditions for driving within these limitations. That is, he or she must ensure that the demands of the driving task are within his or her capability (Figure 2.3). Loss of control occurs when, for

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