CHALLENGES IN SCREENING FOR HIGH RISK ADOLESCENT DRIVERS

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Abstract

This article examines issues in the development of a screening procedure for high collision risk adolescent drivers. Evidence is presented for the hypothesis that the population of high collision risk drivers can be subdivided into distinct subgroups, each one marked by observable behavioral deficiencies which derive from different sources and which predispose drivers to distinct types of collisions. An outline is described of a multi-staged, long-term screening program, entitled the three flag procedure, which could be integrated into current licensing programs. The procedure uses the aggregate results of three assessments taken over time to optimize the sensitivity and the specificity of the procedure. The first flag is triggered by performance measures taken from the theory exam. The second flag is triggered by performance on the driving exam. The triggering of a third flag by the driver's own behavior after a period of unsupervised driving justifies intervention in the form of diagnosis or treatment or both. The three flag procedure refines the current driver's license tests and links them systematically to the violation and collision records of every driver's license candidate, thereby creating a feedback loop that continuously improves the accuracy of the screening criteria. The goal of the three flag screening procedure is to increase the safety of all road users by identifying and rehabilitating high collision risk drivers.

Resumé

Cet article examine la problématique d'une procédure de dépistage de jeunes conducteurs à haute risque de collision. Nous présentons de l'évidence supportant l'hypothèse que la population des conducteurs à haut risque peut être subdivisée en groupes distincts, chacun caractérisé par des comportements déficients observables qui découlent de sources différentes et qui prédisposent les conducteurs à des collisions de types différents. Nous présentons une esquisse d'un program de dépistage à long terme avec plusieurs étapes, appelé la procédure des trois fanions, intégrable dans les procédures existantes d'acquisition d'un permis. La procédure utilise le résultat agrégé de trois évaluations prises dans le temps afin d'optimiser la sensibilité et la spécificité de l'évaluation globale. Le premier fanion est soulevé par les mesures de performances à l'examen sur les connaissances théorique, le deuxième par l'examen pratique. Le troisième fanion est soulevé par le comportement du conducteur après avoir obtenu le permis probatoire, et justifie une intervention sous forme de diagnostic ou d'intervention ou les deux. Cette procédure des trois fanions constitue un raffinement des tests existants pour l'obtention d'un permis liée systématiquement avec le dossier de conduite de chaque nouveau conducteur, et crée une rétroaction qui permettra d'améliorer continuellement la précision des critères de dépistage. Le but de la procédure des trois fanions est l'amélioration de la sécurité de tous les usagers de la route en identifiant et corrigeant les conducteurs à risque élevé.

Introduction

Adolescent drivers, compared with adults, are overrepresented in all levels of injury collisions on a per capita and a per licensed driver basis; from a public health perspective, collision injury remains the most significant cause of adolescent mortality [1]. Screening for high risk drivers is an attractive option given that driver licensing systems have not yet demonstrated the ability to produce fully licensed adolescents who are as safe as adults. The goal of this article is to present an outline of a screening program designed to reduce collision injury, especially among adolescents, by reducing the number and severity of collisions and their rate of recurrence.

With one notable exception, the effectiveness of countermeasures against adolescent collision risk prior to full licensure appears to be explained best by exposure reduction. Policies that reduce exposure totally or partially reduce collision risk, i.e. raising the legal driving age [2], night curfews [3]. Driver education (DE) appears to reduce collision risk if it delays licensure and has no effect if it neither expedites nor delays full licensure [4]. DE appears to increase adolescent collision risk if it expedites the licensing process or allows full licensure at a younger age [5] [6] [7]. The exception is the Swedish program that allows two years of supervised driving practice prior to full licensure. Collision reduction effects have been significant, presumably due to the improved automatization of basic driving control skills that reduces the cognitive load upon inexperienced drivers and allows for better decision making [8].

The only collision counter-measure applied by licensing authorities to fully licensed drivers is the enforcement of the Highway Code, i.e. fines, demerit points or convictions, permit suspensions and revocations. The effectiveness of this countermeasure is problematic for several reasons. One, law enforcement is largely random. Two, even when traffic citations are issued, they are issued more often for violations that correlate lowest with collision frequency than for violations that correlate highest with collision frequency [9]. Three, evidence is weak that legal sanctions or the threat of legal sanctions reduce collision risk. Even driving exposure is not entirely reduced by permit suspension [10]. Four, strict compliance with the law does not always decrease collision risk and illegal driving does not always increase collision risk [11] [12]. Five, the law does not always punish drivers even when their dangerous actions result in collisions. Only 57 percent of collision-involved drivers who clearly committed behavioral errors or unsafe driving acts were charged with violations by police [13]. Six, traffic violations do not trigger a recall of the driver for diagnosis and possible treatment of behavioral deficiencies related to increased collision risk. Finally, even if driving violations triggered a recall of potential high collision risk drivers, this intervention might come too late. Robertson and Baker [14] found that 52 per cent of drivers involved in fatal collisions had no convictions in the three years prior to the fatal collision. The inadequacy of law enforcement to reduce collision risk is apparent. Therefore, what seems to be indicated is a comprehensive program for screening higher collision risk drivers before or soon after they are fully licensed.

We need to clarify at the outset that screening, except in extreme cases, is not intended to deny individuals the opportunity to drive. Excluding a minority of high collision risk drivers would not necessarily reduce overall collision risk [15]. The goal of driver screening is to ensure that drivers who are at high risk of collision involvement will be diagnosed and treated in time to reduce the risk of first time or repeat collision involvement.

Throughout this article we examine the issues and parameters of screening for high collision risk drivers using the epidemiological framework described by Hennikens and Buring [16]. Four related considerations support our decision. First, Waller [17] argues that collision injury can be studied within the disease model. The corollary of this position is that the behaviors that increase the risk of collision injury can also be studied within that model. Second, epidemiology assumes that disease does not occur at random. Collisions may appear to occur at random because they result from the complex interaction of several diverse factors, i.e. human, vehicle, environmental and socio-economic [18]. However, we must assume that the driver behaviors that influence collision risk are not entirely random if we are ever to develop effective behavior-based interventions against collision injury. In principle, drivers are always capable of reducing their risk of involvement in collisions through their own behavior [19].

A third reason for our choice is the epidemiological assumption that the causal or preventive factors related to injury occurrence can be identified through the systematic investigation of different subgroups of individuals within a population. This explicit recognition of the heterogeneous nature of at-risk populations counterbalances potential biases introduced into human factor collision reduction research by the overriding legal and political constraints to consider all driver's license candidates as a homogeneous population meriting standardized treatment. The last reason for the epidemiological approach to the development of a screening procedure is this discipline's long history of successful applications of sound screening principles and methods.

This three part article is organized around the four factors that determine the development of epidemiological screening procedures: suitability of disease, validity of test, and feasibility and effectiveness of program. Part one examines the criteria of diseases suitable for screening in relation to the characteristics of high collision risk drivers. Evidence is presented for the hypothesis that the population of high collision risk drivers can be subdivided into distinct subgroups, each one marked by observable behavioral deficiencies which derive from different sources and which predispose drivers to distinct types of collisions. Part two addresses the question of test validity and proposes a multi-staged, long-term screening program, entitled the three flag procedure, designed to be integrated into current driver licensing systems. Part three examines the feasibility and potential effectiveness of the three flag procedure. The article concludes with a brief discussion of the ethical basis for developing a screening procedure for high collision risk novice drivers.

Suitability of screening subjects

The first factor that determines the development of a screening procedure is the suitability of high collision risk drivers as screening subjects. The three criteria of suitability are: seriousness of the disease, or in this case, driver-centered collision risk; benefit of early treatment, and; prevalence of high collision risk drivers in the screened population. The first criterion, seriousness, examines the related issues of cost-effectiveness and ethics. The costs related to the development and administration of a screening procedure for high risk drivers must be justifiable in terms of eliminating or ameliorating the adverse health consequences of collisions. Ethics evaluates the consequences or costs of failing to detect and treat high risk drivers prior to the occurrence of injury collisions. These issues can only be evaluated properly after calculating all the health, economic and social costs associated with collision injury and comparing these with the costs of developing and administering a screening procedure. For discussion purposes, we assume that the primary prevention of injury collisions is less costly than the loss of life and the cost of secondary and tertiary treatment of collision victims. Part three provides some estimates of the potential cost-effectiveness of screening for high collision risk drivers.

The second criterion of suitability, benefit of early treatment, evaluates whether treating high risk drivers prior to collision involvement is more effective than post collision treatment. The answer is obvious for all injury collisions that would have been prevented entirely or whose seriousness would have been reduced if only the drivers had behaved differently. The third criterion is the prevalence of high risk drivers in the screening population. Coverage will be exhaustive if all new driver's license candidates are screened. However, even if policy makers limit screening to adolescents below majority age, the probability is high that the criterion of prevalence will be satisfied for two reasons. One, increasing proportions of adolescents obtain driving permits at younger ages [20]. Two, studies demonstrate that collision risk increases with decreasing age of newly licensed drivers [21] [22]. According to the above three criteria, it appears likely that high collision risk drivers are a suitable focus for screening.

Before we can detect, diagnose and treat high collision risk drivers, we must answer three related questions: which specific behaviors increase collision risk, who commits these behaviors, and why? Determining which specific behaviors increase collision risk is methodologically difficult because valid information about the specific driver behaviors that precede relatively rare events like collisions is difficult to obtain [23]. Using the best available data from police collision reports, McKnight and McKnight [24] identify 214 specific behaviors as potential contributors to adolescent driver non-fatal injury producing collisions but admit that this classification is "not intended as a taxonomy of crash related behavior". In fact, no authoritative taxonomy of safe or risky driving behaviors exists [1] [19] [25] [26]. Nevertheless, findings from several collision investigation studies converge to confirm the contributory role in collisions of driver errors such as inattention, inadequate visual search, speed too fast for conditions, poor hazard recognition or decision making, alcohol impairment or incapacitation, and improper emergency maneuvers [13] [24] [28] [29].

What is particularly pertinent for purposes of screening is that the above mentioned driver errors or behavioral deficits do not seem to vary as much as one might expect with drivers' age or duration of licensure. McKnight and McKnight [24] found that the errors made by drivers in the 16-17 year age group were similar to those made in the 18-19 year age group and not dissimilar to the errors found by Treat, Tumbus, and McDonald [28] in a study of collisions involving predominantly adult drivers. Hendricks, Freedman, and Zador [13] also found a strong correspondence between the errors reported by Treat et al. [28] and the unsafe driving acts found in their own study of collision involved drivers of all age groups. It would appear that certain types of high collision risk driving errors persist over time.

Waller, Elliot, and Shope [22] arrived at a similar conclusion when they studied 13 809 young adult drivers for an average of seven years and found that rates for at-fault collisions and serious offenses, presumably related to driver intention, decrease more rapidly than rates for not-at-fault collisions and less serious offenses, originally hypothesized by the authors to be more amenable to improvement through driving experience. The authors also found that the proportion of at-fault collisions did not decline over the sequence of collisions for an individual and concluded that "there is only modest evidence of young driver 'learning' from specific incidents" [22].

The possibility exists that some drivers exhibit distinct patterns of driving behavior that persist for many years and that increase risk of specific types of collisions. Hendricks et al. [13] identified seven collision types, each with its own distinct pattern of causal factors, situational characteristics, and driver demographics. For example, one of the seven collision types involved the perceptual error called "Looked, Did Not See" where drivers at intersections where struck when they turned into the paths of other vehicles. Different age groups were overrepresented in different scenarios of this collision type. Younger drivers, below 35 years of age, dominated the scenario where, after "perfunctory checks for cross traffic", they turned right or left and were struck by a vehicle in the cross traffic.

If we combine the findings from all the above studies we can hypothesize the following: critical driver errors, some more than others, appear to persist over time; specific driver errors are associated with specific collision types, and; certain groups of drivers are more prone than others to making certain types of driving errors. The next and most central question in developing a screening procedure is: which drivers are more prone than others to committing high collision risk behaviors?

Peck [27] reviewed research studies that attempted to identify high risk drivers through multivariate analyses of risk factors, e.g. age, gender, and attitude, and driving records and found that driving records, particularly a driver's prior traffic citations, are the most consistent and powerful predictors of subsequent collision risk. Since adolescent driver's permit candidates rarely have a driving history, Peck [27] acknowledges that estimating their collision risk requires the evaluation of "measures that are more distal to actual driving, such as age, socioeconomic status, personality, attitudinal variables, indices of social adjustments, and cognitive functions." For legal and political reasons, these distal measures cannot be used directly to prevent anyone from licensing [1] [30]. For public health reasons, however, distal measures in combination with driver behaviors could help identify high collision risk drivers in order to remedy their particular behavioral deficits and reduce injury risk.

The potential viability of using distal measures to detect high collision risk drivers is improved by the tendency for particular combinations of such measures, i.e. age, gender, attitude, cognitive and psychomotor ability, to cluster together to form distinct low and high collision risk subgroups within the driver population. Gregersen and Berg [31] isolated four high risk and two low risk subgroups after conducting a statistical analysis of lifestyle and collision risk. Beirness and Simpson [32] reviewed several studies that used analytic techniques to identify distinct subgroups of DWI offenders based on measures of personality, i.e. emotional control, thrill-seeking, hostility, social deviance, self-esteem, and cognitive traits. Our concern is not with lifestyles or personalities but only with their respective association with and influence upon high collision risk driving behaviors. Fortunately, the clustering effect is discernible even at the level of driving behavior. Kidd and Huddleston [33] developed a 10-item Driving Practices questionnaire which differentiated with high reliability and validity scores three driver subgroups, safe, unsafe and injured. Hirsch [34] studied adolescent learner drivers and found weak evidence for the potential existence of several high and low risk subgroups composed of distinct combinations of age, gender, and degrees of competence, legality and safety as evaluated by driving school teachers.

Assuming that, after further research, high collision risk subgroups can be identified with reasonable accuracy, the question becomes how do we diagnose and treat these behavioral deficiencies? The answer to this question requires an understanding of the sources of risk taking or unsafe driving. Researchers have identified four distinct sources of driver risk taking behavior. The first two are miscalculation of risks and intentional risk taking for its own sake [19] [25]. Evans [19] adds a third category for intentional self destructive acts or suicide. We add a fourth source of risk taking behavior that is unintentional in the sense that the behavior or its significance is momentarily outside the driver's direct awareness. Evans [19] admits that the "dividing lines between ... categories [of risk taking] are far from sharp." The sources of risk taking may be distinct or they may overlap, i.e. adolescent drivers may seek thrills or they may miscalculate their collision risk or both. Driver intake of drugs, specifically alcohol, is also acknowledged as a major factor in blurring the lines between categories and in increasing driver risk taking within each category. For discussion purposes we examine separately each category.

The claim that a collision results from a driver's miscalculation of risk is based on the assumption that the driver possesses the necessary knowledge and ability to avoid collision involvement.

Scientific explanations for inter- and intra-individual differences in abilities to cope with the driving task are provided by theories such as Information Processing, Behavior Feed-back, and Decision-making that account for both [35]. The results from studies that compare collision risk with measures from instruments based on these theories are mixed. Higher collision risk is associated with information processing deficits such as slower hazard detection [36] and poor selective attention [37]. Cognitive ability, as reflected by higher academic achievement, correlates with lower collision risk [38] [39]. Competence appears to interact with sex in relation to collision risk. Competence, as measured by better performance on the practical road exam, increases collision risk slightly for males and decreases collision risk for females [10]. Poor decision making skills correlate with higher rates of specific types of collision involvement for female drivers only [40]. Competence also appears to interact with age in relation to collision risk. Increased competence in skid control is associated with increased risk for new drivers below 21 years and decreased risk for new drivers 21 years of age and older [41]. Overall, these findings indicate that driving competence is associated with collision risk but that the direction of the association is influenced by interactions with age and sex which may reflect differences in driver motivation and intention to take risks.

The second source of risk taking is driver intention. Attempts to scientifically explain intentional risk taking are found in theories such as Reasoned Action [42], Risk Homeostasis [43], Planned Behavior [44], and Problem Behavior [45]. These theories share the assumption that drivers' intentions and beliefs, as determined by a complex interaction of different factors, can predict drivers' behavior. Weak to moderate empirical support for the claim that collisions result from intentional risk taking is provided by prospective research questionnaires that measure drivers' intentions and beliefs and which have predicted collisions, sometimes several years in advance [46] [47] [48] [49]. In all these studies the drivers' intentions were related to their disregard for clearly defined safety rules and not necessarily to any intention to risk personal injury in a collision. The distinction is important because it might signal a lack of comprehension about the relationship between safety rules and driving outcomes.

The third source of risk taking, suicidal intent, is beyond the scope of this article. Evans [50] reports on several studies that indicate the possibility that many collisions result from suicidal motivation. Schmidt, Shaffer, and Zlotowitz [51] claim that this type of behavior represents less than two percent of all collisions. We hope that collisions due to risk taking with suicidal intent are relatively rare because screening for this behavioral tendency appears to exceed the authority and expertise of any driver licensing agency.

The fourth source is unintentional risk taking, that is, risk taking behavior which is beyond the driver's direct awareness or intentional control. Unintentional risk taking is explained within various theories, i.e. Planned Behavior [44] and Risk Homeostasis [52]. Elander, West, and French [53] consider that some drivers more than others are prone to errors or lapses in their cognitive functioning. Cognitive psychology proposes that well-practiced behaviors, like driving, become habitual or automatic [54]. Unintentional risk taking may be increased during adolescence by person-centered traits like impulsiveness, sensation-seeking, emotional stability, all of which may interact with biopsychosocial maturity and lifestyle influences. The tendency, particularly among adolescents, to violate traffic laws related to sensations, i.e. speed and alcohol, may result directly from certain traits over which the individual may have not yet developed sufficient self-awareness and self-control. Many researchers claim that the underlying principle in adolescent risk taking behavior is that, in comparison with adults, adolescents who are experiencing problems or who are sensation-seekers or both are not necessarily capable of understanding and directing their own driving behavior [45] [55] [56].

To summarize, high risk drivers appear to be suitable subjects for screening provided that the procedures incorporate four insights drawn from the findings of all the above studies. One, it would appear that many driver errors, some more than others, persist over time. We can infer, therefore, that these same errors may be observable to some degree at the time of the driving tests. Two, certain groups of drivers may be more prone than others to making certain types of driving errors. To the extent that this is true, we can focus screening efforts on specific high risk subgroups marked by distinct combinations of cognitive and psychomotor performance, age, gender etc.. Three, it is probable that specific driver errors are associated with specific collision types. This allows us to verify with high accuracy the predictive validity of the screening criteria by examining actual collision reports. Four, the sources of risk taking or deficient behavior are diverse and overlapping. Some novice drivers may be at high collision risk because they lack vehicle control skills, others because they are overconfident and they intentionally violate legal or safe driving rules. Still others may be at high collision risk because they are under the influence of sensation-seeking impulses or strong emotions or drugs or some combination of two or more of all the above risk factors. A comprehensive understanding of how these sources influence driver behavior will provide a solid knowledge base for the diagnosis and treatment of specific high collision risk driver groups. Next we examine the second factor which determines the development of a screening procedure, availability of a test.

Suitability of a test

The second factor that determines the development of a screening procedure is the availability of a suitable test. This factor considers the test itself and the test results. A screening test should be inexpensive, easy to administer, and it should impose minimum discomfort to the individual screened. Due to the desirability of a driver's license, a screening test for high collision risk drivers must also be difficult to cheat. The test results should be valid and reliable. A valid test categorizes correctly license candidates in terms of their collision risk. Correct categorization considers the percentage of true positives (sensitivity) and the percentage of true negatives (specificity). Reliability refers to the consistency of the screening procedures' results when repeat examinations are performed on the same person under the same conditions.

At present, no single test for high collision risk drivers meets all or even most of the above criteria. Townsend, Engel, and Andersen [57] report on two driver attitude tests that produce reasonably valid and reliable results but which could not be used because higher scores could be achieved by cheating. Well-designed psychometric tests that are more difficult to cheat would most likely not be implemented "primarily due to concerns about invasion of personal privacy, discriminatory and unfair practices" [1]. Various efforts to predict future collision risk have produced instruments that suffer from low sensitivity and low specificity [26] [32] [58]. It appears unlikely that any single test will discriminate easily between different levels of collision risk among driver's license candidates.

Therefore, we propose a multistage, long-term screening program, entitled the three flag procedure, designed to detect and rehabilitate novice drivers who are at high risk of injury collision involvement. The three flag procedure is intended to operate in parallel with but distinct from the normal licensing process. The performance criteria for passing the theory and road exams will remain explicit and standardized for all drivers. License examiners will continue to provide candidates with detailed evaluations of their driving performance and recommendations for improvements. However, under the three flag procedure these evaluations and other measures of driver's performance, i.e. length of learning period, will also be recorded on the individual driver's confidential files and linked systematically to driving records (violations and collisions). All performance measures will be analyzed in relation to driving collisions controlling for distal factors, i.e. age, sex, thereby creating a feedback loop that continuously monitors the predictive validity of the various screening criteria.

In essence, the three flag procedure corresponds to conditioning on events (flags) that carry positive information about the risk of a collision, i.e. the risk of a collision given an event is greater than the risk of a collision not having the information that the flag conveys. The following illustration of how the procedure can work is based on data from a study of novice Quebec drivers by Maag, Laberge-Nadeau, and Desjardins [59]. Table 1 gives conditional injury collision risks using the following notation:

IC – an injury collision in the first year after licensing, our target event;
M – being a male, novice driver;
17 – being 17 years old at the time of licensing;
FL – being a fast learner, i.e. a learning period of between 91 and 180 days (90 days was the minimal duration of a learner's permit), and;
E – more than one attempt to pass the theory exam but passing the road exam at the first attempt.

One observes that injury collision risk increases when conditioning on several flags. Thus the subgroup of novice drivers defined by the conditioning variables of exam performance, learning speed, age, and sex has almost double the relative risk of injury collision in the first year of driving than the total population of novice drivers. Conditioning has the additional advantage of reducing the size of the subgroup that should arguably be targeted for intervention, e.g. education, diagnosis of cognitive deficiencies.

Table 1. Injury collision risks in first year of driving for various driver subgroups.

Event(s)	Collision risk	Subgroup size
(IC)	0.0250	111 533
(IC|M)	0.0308	53 069
(IC|M, FL)	0.0326	40 419
(IC|M, 17)	0.0330	12 043
(IC|M,17, FL)	0.0368	7 643
(IC|M,17, FL, E)	0.0487	2 584

The above example shows how predictive power can increase when flags are selectively combined. However, this example does not inform us about the reasons for the increased collision risk of the subgroup in question, and therefore, we have no indication of how to intervene to reduce collision risk. To find effective interventions for the potentially diverse high risk subgroups, the flags should also include criteria that measure directly cognitive and behavioral aspects of driver performance that are potentially treatable.

The first flag should include a detailed analysis of performance on the government theory exam, generally taken to earn a learner's permit. Performance characteristics on the theory exam, i.e. percentage of errors and specific response patterns, are weakly predictive of collision risk when distal factors such as age and gender are included in the analysis [10]. The second flag should include a detailed analysis of the driver's performance on the government road exam. The efficacy of this flag would be enhanced if driving tests were modified according the recommendations of insurers and safety experts [60]. These recommendations include having the examiner rate the candidate's searching and scanning ability and adding a segment to the road test for special maneuvers, i.e. reversing and emergency stopping. Frequency of mirror checks correlate positively with safer driving records [61], anticipation and awareness errors during the road test were found to be predictive of higher collision risk [62], and errors committed during the execution of a special maneuvers segment correlated strongly and positively with subsequent collision risk for women [63].

The third flag in the three flag procedure should examine driving behavior after the candidate has had the opportunity to gain some driving experience. In systems like the Ontario Graduated Licensing system, the third test could be the exit road test administered after at least eight months unsupervised driving. For licensing systems without an exit exam, the third flag for high risk drivers would be self-triggered by a single traffic violation or collision. Because the likelihood is not great that any single flag will have great predictive power, the triggering of only one or two flags would be insufficient to justify an intervention. However, the basic premise of the three flag procedure is that the triggering of a third flag confirms the research-based hypothesis concerning collision risks given previous measures of that individual's driving related performance.

Therefore, when the third flag is triggered the licensing authorities would appear to have justification for believing that the driver in question is at increased risk of first time or repeat collision involvement and for intervening to protect that driver and the public from injury. Intervention could be in the form of diagnostic tests or treatments or both that will enable that individual to remedy her or his particular deficient driver behavior. The nature of the intervention would correspond to the specific high risk profile of the driver.

The three flag procedure, as outlined above, has the potential to meet satisfactorily all the criteria of a suitable screening described earlier. The procedure itself should be as inexpensive to operate as the current driver's permit exam. Start-up costs would include modifications to data entry procedures and record keeping. Modifications to the current driver's permit exam system are recommended but not essential. After these modifications are made, the three flag procedure should be as easy to administer as the current driver licensing system. The costs for the diagnoses or treatment or both of the drivers who test positive, i.e. trigger all three flags, will depend on the specific nature of the drivers' problems.

For example, some drivers appear to be at increased collision risk because they have cognitive deficiencies about safe driving practices. These deficiencies might be remedied easily with targeted education, the safety enhancing effect of which has already been demonstrated [64]. Another subgroup of high collision risk drivers might present symptoms of sensation-seeking (SS), a behavioral tendency with a biological correlate that is strongly associated with increased collision risk [65]. Jonah [65] suggested that problem drivers who come to the attention of the licensing authorities due to the accumulation of collisions and demerit points could be screened to identify high SSs for an educational intervention "focused on deterring them from using driving as a means of stimulation." Other treatment options might require additional driver training. Shinar [66] recommends that efforts should be directed at counseling low-capacity drivers on methods to improve their safety through changes in driving style. Findings by West and Hall [67] and Hirsch [34] suggests that driving teachers are capable of fulfilling this role.

The three flag procedure should not impose greater discomfort on driver's license candidates than current licensing tests. The problem of cheating exists in any licensing test. Candidates may be motivated to mask true behaviors in order to avoid triggering a flag and attracting the attention of the authorities. To some degree, this form of masking already occurs during the road test [68]. The design of the three-flag procedure minimizes the effect of masking by basing the flag-triggering criteria on the correlation between actual driving outcomes and the response patterns of license candidates to the theory and road tests, not merely on the percentage of correct responses and behaviors.

Next we examine whether the results of the three flag procedure meet the criteria of suitability for screening procedures. The results of screening tests should be valid and reliable. A valid test categorizes correctly drivers into high and low collision risk groups. A reliable test is one that produces the same categorization when repeated on the same person. We address first the question of test validity, arguably the thorniest one in terms of screening for driver's licenses. A valid test has high sensitivity, a high percentage of true positives, and high specificity, a high percentage of true negatives. Hennekens and Buring [16] acknowledge that, in practice, there is usually a trade-off between sensitivity and specificity. The trade-off is a result of the fact that no test instrument is perfect and that the disease or trait under investigation, in this case high collision risk, manifests itself on a natural continuum. Therefore some drivers will appear to be at normal low collision risk, others at abnormal or high collision risk and some will fall into the gray zone between the two. In order to operationalize the screening test, a cutoff between low and high risk will have to be determined in a more or less arbitrary manner. Altering the cutoff point influences sensitivity and specificity. A lower cutoff increases sensitivity and improves the ability of the test to avoid missing a high collision risk driver at the expense of decreased specificity and an increased number of low collision risk drivers who will mistakenly be detected by the screening program.

The design of three flag procedure addresses the trade-off problem in three ways. First, the three flag procedure attempts to isolate different high collision risk subgroups, effectively creating multiple screening criteria within the same procedure which should, theoretically, increase sensitivity. Second, the procedure increases specificity by using the aggregate results of three independent measures in series over a period of several months, thereby reducing the number of false-positives and the incidence of unnecessary and inconvenient treatments to low risk drivers. Serial tests also improve the cost efficiency of more complex and sensitive diagnostics and treatments for high collision risk drivers. Finally, the three flag procedure attempts to reduce the arbitrariness of cutoff points by establishing a feedback loop using the endpoint measure of primary interest, i.e. collisions, to verify and update continuously the predictive validity of the risk categorizations.

Assuming that the three flag screening procedure is valid, it must also be reliable. Four threats to reliability are: (1) intrapersonal variation, i.e. biological, psychological, (2) variance within the test method or measurement instrument itself; (3) intrarater variation, and; (4) interrater variation. The design of the three flag procedure attempts to increase reliability by addressing all four sources of variance. First, to control for intrapersonal variation, several measures are taken over an extended time period. Second, to increase the reliability of the test methods and instruments, the procedures are clearly defined and standardized. Computer tests define objectivity in measurement. The scoring criteria on the road test will consist of relatively few categories that require the least amount of subjective judgment or interpretation. Third, intrarater variation is reduced because computer exams ask different questions on repeat tests and the same road evaluator will never test the same candidate twice. Finally, interrater variation will be reduced through routine cross-verification of evaluation scores and evaluator retraining if required.

To summarize, it appears that the three flag procedure has the potential to be a suitable screening test that can provide valid and reliable assessments of a driver's future collision risk. The next and last section examines the feasibility and potential effectiveness of the three flag screening procedure.

Feasibility and effectiveness

Even after high collision risk behavior is determined to be appropriate for screening and a valid test becomes available, it remains unclear whether a widespread screening program for that behavioral deficit should be implemented. Final decisions regarding screening procedures require the consideration of two issues: feasibility and efficacy.

The feasibility of a screening test is determined by three factors: (1) program acceptability; (2) cost effectiveness, and; (3) the yield of the cases. First, the screening program must be acceptable to everyone concerned. Licensing authorities must find the screening procedure quick and easy to administer and license candidates and their families must not be inconvenienced. Like all road safety efforts, i.e. seat belts, a screening procedure for high collision risk drivers is likely to meet with some initial resistance. The design of the three flag procedure promotes acceptability in several ways. One, on the surface the procedure is almost identical to the current driver's license exams which the public already accepts. The only drivers to be affected will be those who consistently demonstrate deficient driving behavior associated with increased collision risk. Two, the modifications that the three flag procedure requires of the licensing authorities are mainly administrative and should add only a limited number of new procedures, most of which entail data entry, i.e. electronically scannable evaluation sheets for road test scores, and analysis. Three, the explicit goal of the screening procedure is to improve the safety of novice drivers without restricting their mobility. The promotion of increased safety without decreasing mobility should earn the support of stakeholders involved in licensing as well as the parents of adolescent drivers, who appear to support safety measures even when mobility is restricted [69]. The support of parents would be critical if their written consent is required to overcome legal challenges to the use of distal measures in evaluating the collision risk of drivers of minor age.

The second factor determining feasibility is cost-effectiveness. Data must be collected and analyzed in order to determine whether the expenditure of resources to detect, confirm and treat a single high collision risk driver can be rationalized within the current licensing systems. Startup costs can be amortized over several years and should not be a real obstacle to acceptability. The real obstacle will most likely be the anticipated costs of the subsequent diagnostics and treatments for drivers who trigger three flags, i.e. test positive for high collision risk. However, these costs can be limited easily because they depend on two factors that are entirely under the licensing authority's direct control: the yield or the number of true positives among all the screened drivers who test positive and policy decisions regarding diagnostics and treatment. The yield can be adjusted by altering the cutoff criteria for triggering flags. The costs of diagnostics and treatment will depend on policy decisions which are determined by multiple factors, the most important one being the level of confidence in the predictive validity of the risk assessments. These issues can be addressed only after further research.

For the sake of argument, consider the following potential cost-benefits of the three flag screening procedure. Dionne and Laberge-Nadeau [70] provide three estimates of the costs for collision death and injury. The first estimates derive from the SAAQ actuarial calculations of compensation payments, $50,647 per death and $9,956 per injury. The second considers human capital costs, i.e. lost production, and values a death at $381,500 and an injury at $20,250. The third estimate derives from Transport Canada which values a human life at 1.5 million dollars and an injury at $80,000. In 1999, among Quebec drivers below the age of 20 involved in collisions, there were 118 deaths and 4,253 non-fatal injuries. Assuming that the three flag procedure is effective at reducing all injury collisions by only 5%, 6 deaths and 212 injuries could have been prevented in 1999. The total cost savings provided by the three flag procedure for that single year would have been approximately 2.4 million dollars using the first estimate, 6.5 million dollars using the second, and over 25.8 million dollars using the third estimate.

The last and most important factor in determining the development of screening programs is effectiveness; do they work? Will the application of the three flag procedure reduce mortality and morbidity due to collisions? Even if the three flag procedure accurately and inexpensively identifies large numbers of individuals at increased collision risk, it will have little public health value if early diagnosis and treatment do not have an impact on the ultimate outcome of cases. Therefore, the first step would be to develop pilot projects to study the relationship between different criteria for triggering flags and actual driving records. If the predictive validity of the criteria can be demonstrated, as hypothesized by the three flag procedure, then further pilot projects can be conducted on the effectiveness of treatment options such as targeted education.

Conclusion

Until driving is fully controlled by intelligent transportation systems, human error will continue to endanger the safety of all road users. A screening procedure like the three flag procedure holds the promise of providing continuous, good quality feedback to the licensing authorities which can be used to identify and treat high collision risk drivers. An argument has been made that this procedure can be politically and socially acceptable as well as cost effective.

Beyond these points there is the ethical consideration that screening exams are indicated whenever the consequences of not screening are serious and irreversible. Screening has been implemented even for rare diseases like PKU (phenylketonuria), which is found in only one in 15,000 babies but which, if it is not detected in time, can lead to severe mental retardation. Some authorities require PKU screening for all newborns, a policy made easier by the availability of simple, accurate and reliable screening tests [16]. With the PKU example in mind, consider that in 1999 in Quebec approximately one in 1,250 adolescent drivers under twenty years of age was fatally injured in a collision; the rate increases to one in 251 for adolescent drivers seriously injured in collisions [71]. In all probability, the physical and mental health consequences for many of these collision victims and their families are serious and irreversible. With sufficient effort, a screening program similar to the three flag procedure could become relatively simple, accurate and inexpensive to operate.

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