

HADDON MEMORIAL LECTURE

Risky business: safety regulations, risk compensation, and individual behavior

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Editors comment: We are proud to be able to bring to our readers this full text version of the Haddon Memorial Lecture delivered at the recent Fifth World Conference on Injury Prevention and Control in New Delhi, India. James Hedlund offers a brilliant review of one of the most important areas of debate in the entire field of injury control. This is the most complete, most perceptive, and well balanced appraisals of this complex issue I have ever read. Take the time to digest it completely. Our thanks to the Insurance Institute for Highway Safety for agreeing to permit us to publish it.

Government regulations and industry practices constrain our behavior in many ways in an attempt to reduce injuries. Safety features are designed into products we use: cars now have airbags; medicine bottles have “childproof” caps. Laws require us to act in a safe manner: we must wear seat belts while driving and hard hats in construction areas. But do these measures influence our behavior in other ways? Risk compensation theory hypothesizes that they do, that we “use up” the additional safety through more risky actions.

This paper surveys risk compensation by reviewing its history, discussing its theoretical foundations, outlining evidence for and against its claims, and providing the author’s own views. It concludes by discussing the relevance of risk compensation for injury prevention workers who seek to reduce unintentional injuries.

The setting: injury prevention strategies and risk compensation

Injury prevention as a discipline began when injuries were understood to be both predictable and preventable. Most injuries are the unintended consequences of individual actions in a risky environment; they are not due to fate or to problem behavior. This understanding led to three fundamental injury prevention strategies, as described in the comprehensive report *Injury in America*¹:

- Persuade persons at risk to change their behavior,
- Require behavior change by law or administrative rule,
- Provide automatic protection through product and environmental design.

Injury prevention policymakers and workers generally agreed on the relative priorities of these strategies. As *Injury in America* again reports: “Each of these general strategies has a role in any comprehensive injury-control program; however a basic finding from research is that the second strategy—requiring behavior change—will generally be more effective than the first, and that the third—providing automatic protection—will be the most effective”.¹

The favored strategies implicitly assume that people will not react to safety laws or safer products in ways that would reduce or eliminate their effect. But of course they may. This behavioral reaction in response to safety measures has been called many things. In this

paper, *behavioral adaptation* describes all behavioral change in response to perceived changes in risk and *risk compensation* describes the special case of behavior change in response to laws and regulations. The distinction becomes murky at times: if a new safety feature appears on all chain saws, any behavioral reaction won’t depend on whether the feature is required by government regulation or adopted voluntarily by all manufacturers. The risk compensation definition adopted here focuses on the injury prevention strategies of greatest controversy, where government attempts to increase safety by law or regulation.

A brief history of risk compensation

We all change our behavior in response to some changes in perceived injury risk. Most obviously, we may take additional precautions if we believe our risk has increased. When roads and sidewalks are icy, we may walk more carefully for fear of falling and we may drive more slowly to be sure that we can stop safely. But it is not at all obvious that we change our behavior in response to every increase or decrease in risk. The heart of the risk compensation debate lies in determining which risk changes will produce compensating behavioral change.

The early risk compensation literature deals with road safety, as traffic crashes have been the largest cause of accidental injury and death in motorized countries and consequently produced extensive safety regulations. By mid-century behavioral adaptation had been recognized but not seriously studied.²

RISK COMPENSATION AND ECONOMICS: PELTZMAN’S EVALUATION OF MOTOR VEHICLE SAFETY STANDARDS

Risk compensation in response to government actions became a public issue with University of Chicago economist Sam Peltzman’s 1975 paper “The effects of automobile safety regulation”.³ Nine years earlier, in 1966, the United States Congress established the National Highway Traffic Safety Administration’s predecessor, appointed William Haddon as its first administrator, and directed it to improve motor vehicle safety. By the end of 1968 the agency had issued 29 Federal Motor Vehicle Safety Standards (FMVSS) applying to new motor vehicles. Some FMVSS sought to prevent crashes by setting standards for brakes,

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tires, and mirrors. The majority sought to reduce crash injuries by requiring features such as seat belts, shatterproof windshields, and energy-absorbing steering columns.

Peltzman evaluated the effects of the FMVSS: had they in fact improved safety as anticipated? He began with the assumption that we are rational economic consumers who act in our own best interests. If we have more of something than we want, we will (if we can) exchange it for something else that we desire. Peltzman considered safety (or risk) an economic good that we will trade with other goods in the same way. If our car is safer than we want it to be, then we will drive faster, trading safety for time. In his words, we will trade safety for “driving intensity”.

Peltzman tested his idea with an econometric analysis of FMVSS effects. He concluded that the standards were ineffective: they had no effect on overall traffic fatalities; they may have saved some auto occupants’ lives while increasing pedestrian deaths.³

This conclusion startled the road safety community and challenged the role of government in attempting to improve safety through regulation. In Peltzman’s view, government regulation was useless and perhaps even counterproductive.

Peltzman’s paper prompted a lively debate over the next 20 years. Some papers criticized or supported Peltzman’s study; others offered new analyses.^{4–19} The debate centered on Peltzman’s statistical analyses. Issues included the variable used to measure FMVSS effects, the time period analyzed, the regression equation’s functional form, what other factors should be included in the model as controls and how they are best measured, and how to account for motorcycles, trucks, and other vehicles not regulated in the same way as passenger vehicles. Each choice may affect the results substantially. For example, Graham and Garber recalculated Peltzman’s regression estimates using absolute instead of logarithmic variables. Their estimates suggested that regulation prevented roughly 5000 fatalities between 1966 and 1972, rather than causing about 10 000 deaths as Peltzman concluded.¹⁵

Blomquist reviewed 11 of these studies.²⁰ His summary of their aggregate evidence is that the FMVSS increased safety for passenger car occupants, but probably not as much as had been predicted, and reduced safety for non-occupants, but not enough to offset the benefits to occupants. In a recent critical review, Levy and Miller agree that the FMVSS improved occupant safety but find only weak support for any effect on non-occupants.²¹

This debate did not affect the FMVSS: they remained in force, without serious challenge (indeed, manufacturers had adopted many of the FMVSS voluntarily before they were required by regulation). But Peltzman’s paper introduced risk compensation as a serious road safety issue.

RISK COMPENSATION AND PSYCHOLOGY: WILDE’S RISK HOMEOSTASIS THEORY
G J S Wilde (Queen’s University, Ontario) considered risk compensation from a psychological rather than economic point of view.

With his 1982 *Risk Analysis* paper, “The theory of risk homeostasis: implications for safety and health”,²² its four accompanying commentaries,^{23–26} and Wilde’s response,²⁷ his ideas attracted substantial attention.

In Wilde’s view, risk is an inherent part of our psychological makeup. Not only can we not avoid risk, we need risk. Wilde hypothesizes that we each have a “target level of risk” and measure risk on our own “risk thermostat”. If the perceived risk of a situation exceeds our target level, we will act to reduce it. And if the perceived risk is lower than our target level, we will attempt to increase our risk back to our target level through more dangerous actions.

Wilde’s name for this process is risk homeostasis, by analogy with the self-regulatory and unconscious manner in which we maintain our body’s temperature. Risk homeostasis is then an extreme form of behavioral adaptation: not only do we modify our behavior in response to external changes designed to make us more or less safe, but we seek to counteract these changes completely and return to our desired risk level. Because the risk in our environment constantly changes, we constantly are forced away from our target risk level, but we always move back toward it, always countering external influences (such as injury prevention measures) that attempt to decrease or increase our risk.

Wilde developed a mathematical formulation of risk homeostasis in road safety: the “accident rate per time unity of driver exposure is invariant regardless of road geometry” (or, for that matter, regardless of anything else).²² In other words, my accident rate per hour of travel on a high-speed divided motorway is the same as my rate per hour on a low-speed neighborhood street. Wilde described his theory in catchy language: “the sum of the sins is constant”. Others called it even more picturesquely “the law of conservation of misery”. Wilde extended risk homeostasis beyond road safety: “Risk homeostasis may thus apply not only to road use, but also to industrial safety, sports, making love, smoking, drinking, doing home repairs, climbing ladders, physical exercise, investing money, gambling, and who knows how many other activities”.²⁸

Risk homeostasis challenges the foundations of injury prevention strategy. It holds that the only effective safety measures are those that alter my desired risk level. Anything that merely modifies the environment or that regulates my behavior without affecting my target risk level is useless.

Wilde’s risk homeostasis theory was challenged by Leonard Evans, Frank McKenna, and others. Wilde published extensively over the following 10 years, engaging his critics in running debates.^{29–42} Wilde’s 1994 book *Target Risk* summarizes his views for a general audience.²⁸

RISK COMPENSATION AND PUBLIC POLICY: ADAMS’ CAMPAIGN AGAINST SEAT BELT USE LAWS
John Adams (University College, London) began investigating the effects of seat belt use laws in his work on transportation planning, in which he opposed policies that increased the

number of private cars. He concluded that seat belt laws were not effective. In fact, as Peltzman concluded for the FMVSS, Adams believed that belt laws (and other vehicle safety measures) reduced risk for passenger car occupants but increased risk for pedestrians and cyclists. He adopted much of Wilde's risk homeostasis as the behavioral basis for his findings.

Adams' goal was to influence public policy. He opposed seat belt laws while they were being debated in the British Parliament. His primary method for estimating belt law effects was to compare overall road fatality trends in countries with and without belt laws. His results were easily understood by newspaper readers and politicians alike. He also stated his thoughts clearly, succinctly, and controversially: "protecting motorists from the consequences of bad driving encourages bad driving".⁴³ His 1995 book *Risk/John Adams* summarizes and extends his ideas in a broad discussion of risk in society.⁴⁴

Adams' views and analyses on belt law effectiveness were countered forcefully by many, notably Murray Mackay. Critics argued that Adams' methods were suspect. In particular, overall road fatality trends are affected by many factors and a detailed statistical analysis with good data and appropriate controls is needed to evaluate belt law effects.

After extensive debate, Parliament adopted a belt use law for front seat occupants effective in January 1983 which would lapse after three years unless Parliament voted again to continue it. Evaluations of data from the first post-law year by Mackay,⁴⁵ the British Department of Transport,⁴⁶ and statisticians from the London School of Economics⁴⁶ all concluded that passenger car front seat occupant casualties decreased substantially. Adams countered by claiming that the observed decrease was due to a well-established downward trend in casualties and to a campaign to reduce drunk driving.^{43 44}

In 1986, Parliament voted to retain the seat belt use law. Irwin provides a thoughtful view of scientific and political issues throughout the British seat belt law debate.⁴⁷ Adams⁴⁸ and Mackay⁴⁵ give contemporary views from both sides. Evans⁴⁹ and Adams⁴⁴ analyze the issues and evaluate the results from a longer perspective.

RISK COMPENSATION IN 2000

Peltzman's, Wilde's, and Adams' papers prompted debate in journal, at conferences, and in books.^{28 44 49-54} In terms of ideas and controversy, though, little has changed in the past decade. An Organization for Economic Co-operation and Development (OECD) report, prepared by an international working group, gives an excellent, thorough, and dispassionate summary of risk compensation theories and evidence. The report concludes that "... behavioural adaptation to road safety programmes does occur although not consistently. ... behavioural adaptation generally does not eliminate the safety gains from programmes, but tends to reduce the size of the expected effects".⁵⁵ The extreme views of risk homeostasis have attracted little support.

Evidence for and against risk compensation

The evidence falls into two broad categories: evaluations and experiments.

EVALUATIONS

Risk compensation occurs if people react to a safety law or regulation by acting less safely. It can be evaluated either by examining individuals to observe if their actions have changed or by examining aggregate data to measure the law's or regulation's effects.

(1) Individual actions

Was explicit compensating behavior observed? This apparently logical way to evaluate risk compensation is virtually impossible to carry out satisfactorily in practice, for two reasons. First, risk compensation predicts that behavior will change but does not predict how it will change, so we don't know what to observe. Behavior may change in ways that are not at all obvious. Wilde suggests that measures to reduce drunk driving may in fact have a road safety benefit but also may cause those who would have driven drunk to act in more risky ways when not on the road.²⁸ Or, compensating behavior may take place well after the fact. Adams suggests that laws requiring traffic to stop when children are entering or leaving a school bus may encourage children to be careless, so that in later years they are in danger when entering or leaving a transit bus.⁵⁶ No study can examine all possible ways in which compensating behavior might occur. Second, behavior change is difficult to measure. We may be able to measure large changes such as performing a task more quickly but usually cannot measure more subtle changes such as increased carelessness.

A few studies have examined driving behavior changes after various road safety measures. They typically find no effects for measures to protect occupants in the event of a crash (such as seat belts) but may find effects for measures that attempt to prevent crashes by improving vehicle performance (such as better brakes or tires). For example, O'Neill *et al* studied drivers in Canada and England after seat belt use laws were implemented.⁵⁷ They examined travel speeds and following headways and reported no evidence of riskier behavior due to the belt use laws. Sagberg *et al* observed travel speeds and following headways for Oslo taxi drivers with and without airbags and antilock brakes.⁵⁸ They reported shorter headways for cars with antilock brakes but no significant difference for cars with airbags. Wilde reports on a study of Munich taxicabs with and without antilock brakes.²⁸ The study found that drivers with antilock brakes changed their behavior by driving faster and braking harder than before.

Most important, even if observations show that behavior has changed, the effect on crashes or injuries is unclear. Faster driving may not necessarily lead to increased crash risk; different methods of sawing wood may not lead to increased injuries. Risk compensation is relevant only if a safety measure produces

behavior change that in turn increases risk. This must be evaluated with aggregate data.

(2) *Aggregate data*

Were injuries reduced as intended? The question requires all the standards of a good evaluation: a sound experimental design, good data, good controls for other factors, and appropriate statistical analyses. Even well done safety measure evaluations may fall short. While overall injury counts are high, individual injuries typically are rare events. Data on which to base an evaluation frequently are inaccurate or imprecise. Effects may be small: most traffic safety measures do well to reduce casualties by 10%. Safety measures seldom are implemented in controlled experimental conditions but are put in place in the real world, where many other changing factors can affect the results.

The literature contains tens of thousands of studies evaluating safety measures. For example, a literature search produced 54 078 abstracts or titles that might be relevant to nine motor vehicle injury prevention strategies.⁵⁹ But good studies are rare. For instance, a meta-analysis of drunk driving prevention and control literature from 1960 through 1991 identified 6500 documents, of which only 125 passed minimal standards of scientific rigor and quality.⁶⁰

To test for risk compensation a high quality study should do two additional things. First, it should compare the effect with what was predicted in the absence of any compensating behavior change. Predictions are of course imprecise. However, results falling far short of predictions may suggest risk compensation. Second, the study should examine system effects. Safety measure evaluations frequently fail to look beyond the population directly affected by the measure: for example, seat belt evaluations often consider consequences only to vehicle occupants.

Evans provides a good sampling of actual and predicted effects.^{49 61} He examined 24 studies from the road safety literature and compared the effects predicted and actually realized. For measures designed to increase safety he found examples where safety increased even more than expected, about as expected, less than expected, where the measure did not change safety at all, and where the measure actually decreased safety—a perverse effect. Similarly, for measures expected to decrease safety, he found the same range of effects, from a decrease greater than expected to an actual increase in safety—an equally perverse effect. Evans concluded that behavioral adaptation to traffic safety measures is widespread, that the effects can vary widely, and that there is no evidence for the complete compensation predicted by risk homeostasis.

Many of Evans' measures are not laws or regulations, so his conclusions on behavioral adaptation cannot be applied immediately to risk compensation. His studies also do not report on system effects. To examine both issues, consider three road safety areas where risk compensation issues have been raised frequently: vehicle safety standards, seat belt laws, and motorcycle helmet laws.

Vehicle safety standards—The evaluations discussed previously typically examine data on all road fatalities, thus including all reasonable system effects. Several evaluations also compare results with predictions. Blomquist's summary suggests that the FMVSS did make occupants safer, but less than expected; that they may have increased risk for non-occupants; and that they increased overall road safety: in short, they may have produced some risk compensation, but their overall effect was positive.²⁰ Levy and Miller's review questions the increased risk for non-occupants.²¹

Seat belt use laws—The British seat belt law studies discussed previously consider system effects on all road users. The results also are consistent with the well-established protective benefits of belts in a crash and with the observed increases in belt use resulting from the law.⁴⁹ As noted above, Adams challenged these findings.⁴⁴ Evans compared United States seat belt law results with predictions.⁴⁹ He found observed fatality reductions close to, but typically less than, predicted reductions. He attributes this not to risk compensation but to two other factors: that belted drivers are generally safer drivers than unbelted, and that belt use rates are lower at night than during the day (when belt use observations typically are taken).

Many other belt use law evaluations have been published with far less conclusive results. Most do not consider effects on other road users. Levy and Miller reviewed a few studies that do examine possible risk compensation.²¹ They conclude that belt use laws generally improved vehicle occupant safety but that several studies reported evidence on non-occupant casualties consistent with compensating behavior.

Motorcycle helmet use laws—These state laws in the United States provide an excellent test of risk compensation for several reasons. Helmets clearly reduce head injury in a crash, and head injury is the leading cause of death for motorcyclists. Motorcyclists are very aware of the protection offered by a helmet, but some motorcyclists dislike helmets for various reasons. The potential risk compensation mechanism is obvious: a motorcyclist who would not choose to wear a helmet may drive more recklessly if helmet use is required by law. Helmet use depends strongly on the presence of a law: about half of all motorcyclists wear helmets if there is no law but almost all wear helmets if there is a law. States have enacted, repealed, and re-enacted helmet laws many times over the past 35 years, providing many opportunities to measure law effects. Finally, system effects from helmet use laws are negligible, since motorcycle crashes very rarely cause serious injury to anyone other than motorcyclists themselves.

At the request of Congress, in 1991 the United States General Accounting Office reviewed all 46 available helmet law effectiveness studies.⁶² It concluded that helmet laws reduced motorcyclist fatalities by 20% to 40%, a result in reasonable agreement with helmet effectiveness in a crash. Evans reaches similar conclusions,⁴⁹ as do more recent evaluations.⁶³⁻⁶⁵

From this evidence, motorcycle helmet laws have produced no detectable risk compensation.

Risk compensation in other settings—Several recent studies examine risk compensation in response to both aggregate and specific consumer product and workplace safety regulations. The following examples give a flavor of the results. Each study discusses relevant earlier research.

Consumer product regulations: Since its establishment in 1972, the United States Consumer Product Safety Commission (CPSC) has issued many regulations affecting different products. Early studies typically concluded that CPSC's regulations did not reduce consumer accidents.⁶⁶ Recent studies of some specific standards have found safety benefits.

Bicycles: Magat and Moore concluded that bicycle safety standards in the United Kingdom and the United States have reduced bicycle accidents.⁶⁷

Child-resistant medicine bottle caps: Rodgers found "persuasive and robust evidence of the effectiveness of child-resistant packaging for oral prescription drugs" in the United States.⁶⁸ In Sweden, Assargård and Sjöberg concluded that the caps have been highly effective in reducing accidental poisoning from liquid paracetamol among children.⁶⁹

Cigarette lighters: Viscusi and Cavallo concluded that lighters with child-resistant features cause some consumers to reduce the care they take with lighters but that their overall effect has been to improve safety.⁷⁰

Power lawn mowers: Beginning in 1982, all walk-behind mowers sold in the United States were required to have a safety shield and a "deadman" clutch that stops the motor when the handle is released. Alexander concluded that the regulations increased injuries per population.⁷¹ Moore and Magat, on the other hand, found evidence suggesting that the regulations reduced injuries.⁷²

Workplace safety regulations: Beginning in the early 1970s, the United States Occupational Safety and Health Administration (OSHA) has set numerous safety standards for workplace equipment design (such as width and spacing requirements for handrails) and performance (strength requirements for ladder rungs) as well as worker conduct (speed limits while driving a forklift). OSHA enforces these standards through inspections and penalties for violations. Early analyses found little or no effect on accidents.⁷³ Lanoie's review of more recent research concluded that the standards have reduced injuries of certain types and also reduced overall injuries in firms that were inspected.⁷⁴ Using data from 1973–83, Viscusi found a "modest" effect on injuries resulting in lost workdays but not on overall injuries.⁷⁵

Protective equipment for loggers: Klen studied both individual behavior and overall accident rates after protective equipment (such as helmets, eye protectors, safety gloves and boots) was required or used voluntarily by Finnish loggers.⁷⁶ He concluded that most loggers felt safer with this equipment and nearly half reported that they worked more quickly

and carelessly. The equipment changed the injury distribution, reducing injuries to areas directly protected by the equipment but increasing other injuries. Overall injury rates decreased somewhat.

(3) Summary

This brief review of the evaluation evidence strongly suggests that various amounts of risk compensation have occurred in response to some safety measures but not in response to others. The review also illustrates the difficulty of accurately establishing or refuting, much less measuring, risk compensation. Risk compensation proponents acknowledge this dilemma: "... the multi-dimensionality of risk and all the problems of measuring it discussed earlier, preclude the possibility of devising any conclusive statistical tests of the [risk compensation] hypothesis".⁴⁴

EXPERIMENTS

Controlled experiments in laboratory settings eliminate much of the messiness and variability of real world evaluation. In these studies, subjects typically perform some task for a reward that depends on their performance. They also face penalties for an "accident". The experimenter varies the reward and the accident risk and observes changes in the subject's performance. Two examples illustrate these experiments. For a summary of many experimental studies on risk compensation, see Glendon *et al.*⁷⁶

Jackson and Blackman report on a study in which subjects "drove" a driving simulator through a specified route.⁷⁷ Subjects received a monetary reward for completing the route quickly. They were penalized for "accidents" or for being caught speeding. The speed limit and the penalties for speeding and accidents were varied. The authors found that, "consistent with risk homeostasis theory, increased speed limit and reduced speeding fine significantly increased driving speed but had no effect on accident frequency. Moreover, increased accident cost caused large and significant reductions in accident frequency but no change in speed choice".

Wilde reports on several experiments in *Target Risk*.²⁸ In a typical experiment, a subject is seated at a computer screen in which a large square appears at random times. The subject's objective is to press a button as close to but no sooner than 1.5 seconds after the square appears. The subject's reward increases the closer the response is to 1.5 seconds. Responses sooner than 1.5 seconds receive no reward and may impose a penalty. In this and many similar experiments, Wilde finds evidence for risk compensation: as the penalty for responding too quickly increases, response times also increase so that the number of responses drawing penalties decreases.

These experiments show clearly that people modify their behavior in response to changes in the reward and penalty structure of their environment. This is hardly news: behavioral change in response to reward and risk changes has been observed in decisions to invest, to buy

insurance, and in many other ways. But this is far from relevant to injury prevention. Laboratory experiments carry no risk of injury or death. Performance in the laboratory likely has little or no relation to risk compensation. Risk compensation proponents recognize this: "Resorting to laboratory and simulation studies may be methodologically pleasing (and morally innocuous), but it is doubtful that the theory in question [risk compensation] can ever be cogently tested under such contrived conditions. ... In other words: simulation of risk, like a sham duplicating the real thing, is a contradiction in terms".²⁷

THEORY

If experiments cannot provide useful evidence, and if evaluations are contaminated by poor data and uncontrolled factors, we are left with theory. Are we economic beings who constantly balance costs and benefits in deciding whether to speed up a bit on this road (knowing that our airbag will help protect us if worst comes to worst)? Are we constantly motivated by our desire for risk? Both common sense and the evidence reviewed above suggest that these factors influence our actions but do not determine them absolutely. How much will they influence our response to a safety measure? For this we must be able to predict our responses and measure the results, which leads right back to evaluation.

A personal view of risk compensation

Behavioral adaptation and risk compensation clearly occur in some situations. We react to changed conditions; we are famous for not always doing as we are told or as is expected of us. On the other hand, I believe the evidence is overwhelming that every safety law or regulation is not counterbalanced by compensating behavior.

Thus the issue becomes not yes or no, but when and how much. When may compensation occur in response to a safety measure? How likely is it to occur? What are its possible consequences, both direct and indirect?

I suggest that four factors influence adaptation and compensation in response to safety measures. Each factor has several aspects, and the factors interact with each other. Each has been suggested previously, for example by OECD.⁵⁵ The four factors lead to overall guidance and to principles for action.

(1) VISIBILITY

How obvious is the change produced by the safety measure? Do I even know there has been a change?

Some changes are very obvious, especially those that affect performance through direct feedback: vehicle brakes and studded tires, child-resistant caps on medicine bottles, protective equipment for athletes or workers. Other changes are apparent but easily overlooked. I "know" there's a smoke detector outside my study, but I think about it only when I replace its battery. Finally, some changes may be completely or psychologically invisible. The

only way I learn about them is from manufacturer or media information. Many features to reduce or prevent injuries to vehicle occupants, such as side door beams or penetration-resistant windshields, are invisible for all practical purposes.

Laws and regulations restricting my behavior can be very obvious, if advertised and enforced vigorously. If not, they too may be invisible.

Rule 1: If I don't know it's there, I won't compensate for a safety measure.

(2) EFFECT

How does the change affect me, both physically and mentally?

This factor has several dimensions. First, how does the change affect my physical performance of the task, through direct sensory feedback or otherwise? Is it annoying, like child-resistant medicine caps that too often are adult-resistant as well? Is it physically uncomfortable, as helmets are for some motorcyclists? Does it make the task easier, like improved vehicle handling or brakes? Or more difficult, like the lawnmower deadman switch that requires me to hold the handle constantly?

Second, how does the change affect my attitude? Does it annoy me, like a requirement to wear seat belts may for a libertarian? Or do I welcome it, like a guardrail added to a dangerous curve? These two dimensions clearly interact, as changes affecting my performance also may affect my attitude.

Finally, how does the change affect my perception of risk? Do I feel safer because I am wearing a bicycle helmet? Do I feel that risk has been eliminated, as the *Titanic's* passengers and crew may have believed? Or do I think the change has little or no effect on my risk, because I felt there was no risk in the first place, because I believe the measure is ineffective, or because I don't know that anything has changed?

Rule 2: If it doesn't affect me, I won't compensate for a safety measure.

(3) MOTIVATION

What influences my behavior? What is my motivation in doing the task? What is my economic utility function? What are my psychological needs?

This factor is key to most risk compensation theory discussions. Economists hold that I am influenced by economic goals. If I am driving, they believe my only goal is to be transported in the shortest time and to avoid the economic costs of crashes and injuries. So if my car becomes safer, either because it is less likely to crash or less likely to injure me if it does, and if the additional safety is not useful to me, then I will drive faster. The same reasoning applies if I am required to use safety equipment such as seat belts or cycle helmets. In the workplace, if my salary depends on my output, my goal is to maximize my production while keeping my injury risk below an acceptable level.

Risk homeostasis theorists, on the other hand, hold that my basic goal is to maintain my desired risk level: "It is primarily risk to self that governs behaviour on the road".⁴⁴

Both views are simplistic. I am motivated by many factors, both economic and behavioral. On the road I want to get from here to there while avoiding both personal injury and crashes. I may or may not care about saving time: while late for an appointment, I may cherish every second; on a casual trip, I may decide to take a longer and slower route because I enjoy the scenery.

I also am motivated by habit and by my desire to simplify decisions. While I may make more or less rational decisions in an unfamiliar situation, I quickly fall into habits and put many daily operations on “automatic pilot”. So I don’t think each time about how fast I drive down my neighborhood street, I do it just as I always have done. Once accustomed to wearing a seat belt in a car or a hard hat on a construction site, many of us do it every time without thinking.

These factors all influence my motivation to compensate for safety changes. If I am motivated to change behavior, I may well compensate. But if there is no motivation for behavior change, I won’t.

Rule 3: If I have no reason to change my behavior, I won’t compensate for a safety measure.

(4) CONTROL

How much do I control the situation? Can I change my actions even if I want to?

Workplace situations frequently are tightly controlled by rules, supervisors, and the physical environment, so may allow little opportunity for behavioral change. Piecework settings provide more flexibility and freedom. Driving allows considerable freedom: traffic laws provide nominal control, but since most laws are not enforced rigorously, individual drivers have considerable latitude for their actions. Household settings allow virtually complete control.

Sport provides interesting examples of the interplay between injury prevention, compensation, and control. In many sports, such as ice hockey and American football, players are required to wear protective equipment. Some players have compensated by acting more violently within the confines of the rules. In some instances this has led to rules changes to control player actions more tightly.⁷⁸

Rule 4: If my behavior is tightly controlled, I won’t compensate for a safety measure.

A COMPENSATION INDEX

Each of these four factors—visibility, effect, motivation, and control—is far more complex than this simple discussion suggests. But together they provide a useful framework for considering potential risk compensation in response to a safety measure: a highly imprecise compensation index. Assess each factor subjectively, from “no, not at all, zero” to “maybe, moderate, some” to “yes, strong, a lot”. As a first approximation:

- Compensation is unlikely if any of the four is zero: the measure is invisible, doesn’t affect me, or I have no motivation or no freedom to change my behavior.

- As all factors reach moderate levels, the likelihood of compensation increases.
- If each is high, behavioral compensation is likely: the measure is highly visible, affects me substantially, I have good reasons to change behavior and I have the freedom to do so. Then I will consume at least some of my increased safety as performance. And even then it’s unclear whether the overall effect will be to compensate partially, completely, or more than completely for the safety measure.

Implications for injury prevention

Risk compensation is important for everyone who plans and implements injury prevention measures. In summary:

- *Risk compensation can occur —people are not machines.* We all change our behavior in response to changes in our environment. Safety measures change our environment, so we may change our behavior in response to them. Many rational and behavioral factors influence whether and how our behavior will change. Never assume that behavior will not change.
- *Four factors influence risk compensation—visibility, effect, motivation, and control.* Risk compensation occurs only in certain circumstances. The four factors and the compensation index help analyze an injury prevention measure to estimate whether risk compensation is likely or not.
- *To reduce or eliminate risk compensation, use measures rating low on at least one factor.* Prefer measures that are invisible to people, or that do not affect their actions or attitudes, or for which they have no motivation or freedom to change behavior.
- *Consider system effects.* Injury prevention measures may have effects beyond the individual actions they influence directly. These effects may be harmful or helpful. Always consider potential system effects.
- *Don’t over-predict benefits.* Many injury prevention measures promise more benefits than they deliver, due to bad science, political pressures, or failure to consider risk compensation or system effects. While calm and realistic benefit estimates are difficult to produce, unduly optimistic predictions will hamper injury prevention efforts in the long run.
- *Trading safety for performance isn’t necessarily bad.* Safety isn’t society’s only goal. All action produces risk. As society and as individuals we constantly balance performance and risk (in many dimensions of each). If some safety benefits predicted for an injury prevention measure become performance improvements instead, society overall may benefit.

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- 1 Committee on Trauma Research, Commission on Life Sciences, National Research Council, and the Institute of Medicine. *Injury in America: a continuing public health problem*. Washington, DC: National Academy Press, 1985.
- 2 Smeed R. Some statistical aspects of road safety research. *Journal of the Royal Statistical Society Series A* 1949;112:1–34.
- 3 Peltzman S. The effects of automobile safety regulation. *Journal of Political Economy* 1975;83:677–725.
- 4 Joksch HC. Critique of Sam Peltzman's study: the effects of automobile safety regulation. *Accid Anal Prev* 1976;8:129–37.
- 5 Peltzman S. The effects of automobile safety regulation: a reply. *Accid Anal Prev* 1976;8:139–42.
- 6 Joksch HC. The effects of automobile safety regulation: comments on Peltzman's reply. *Accid Anal Prev* 1976;8:213–14.
- 7 Robertson LS. A critical analysis of Peltzman's "The effects of automobile safety regulation". *Journal of Economic Issues* 1977;11:586–600.
- 8 Peltzman S. A reply to Robertson. *Journal of Economic Issues* 1977;11:672–8.
- 9 Robertson LS. Rejoinder to Peltzman. *Journal of Economic Issues* 1977;11:679–83.
- 10 Robertson LS. State and federal new-car safety regulation: effects on fatality rates. *Accid Anal Prev* 1977;9:151–6.
- 11 Robertson LS. Automobile safety regulations and death reductions in the United States. *Am J Public Health* 1981;71:818–22.
- 12 Robertson LS. Automobile safety regulation: rebuttal and new data. *Am J Public Health* 1984;74:1390–4.
- 13 Robertson LS. Reducing death on the road: the effects of minimum safety standards, publicized crash tests, seat belts, and alcohol. *Am J Public Health* 1996;86:31–4.
- 14 Crandall RW, Graham JD. Automobile safety regulation and offsetting behavior: some new empirical estimates. *American Economic Review* 1984;74:328–31.
- 15 Graham JD, Garber S. Evaluating the effects of automobile safety regulation. *Journal of Policy Analysis and Management* 1984;3:206–24.
- 16 Orr LD. The effectiveness of automobile safety regulation: evidence from the FARS data. *Am J Public Health* 1984;74:1384–9.
- 17 Zlatoper TJ. Regression analysis of time series data on motor vehicle deaths in the United States. *Journal of Transport Economics and Policy* 1984;18:263–74.
- 18 Garbarz C. How effective is automobile safety regulation? *Applied Economics* 1990;22:1705–14.
- 19 Chirinko RS, Harper EP Jr. Buckle up or slow down? New estimates of offsetting behavior and their implications for automobile safety regulation. *Journal of Policy Analysis and Management* 1993;12:270–96.
- 20 Blomquist GC. *The regulation of motor vehicle and traffic safety*. Boston, MA: Kluwer Academic Publishers, 1988.
- 21 Levy DT, Miller T. Review: risk compensation literature, the theory and evidence. *Journal of Crash Prevention and Injury Control* 1999 (in press).
- 22 Wilde GJS. The theory of risk homeostasis: implication for safety and health. *Risk Analysis* 1982;2:209–25.
- 23 Slovic P, Fischhoff B. Targeting risks. *Risk Analysis* 1982;2:227–34.
- 24 Graham JD. On Wilde's theory of risk homeostasis. *Risk Analysis* 1982;2:235–7.
- 25 Orr LD. Goals, risks, and choices. *Risk Analysis* 1982;2:239–42.
- 26 Cole GA, Withey SB. The risk of aggregation. *Risk Analysis* 1982;2:243–7.
- 27 Wilde GJS. Critical issues in risk homeostasis theory. *Risk Analysis* 1982;2:249–58.
- 28 Wilde GJS. *Target risk: dealing with the danger of death, disease and damage in everyday decisions*. Toronto: Castor and Columba, 1994.
- 29 McKenna FP. The human factor in driving accidents: an overview of approaches and problems. *Ergonomics* 1982;25:867–77.
- 30 Wilde GJS. Evidence refuting the theory of risk homeostasis? A rejoinder to Frank P McKenna. *Ergonomics* 1984;27:297–304.
- 31 McKenna FP. Do safety measures really work? An examination of risk homeostasis theory. *Ergonomics* 1985;28:489–98.
- 32 Wilde GJS. Assumptions necessary and unnecessary to risk homeostasis. *Ergonomics* 1985;28:1531–8.
- 33 McKenna FP. Evidence and assumptions relevant to risk homeostasis. *Ergonomics* 1985;28:1539–41.
- 34 McKenna FP. Behavioural compensation and safety. *Journal of Occupational Accidents* 1987;9:107–21.
- 35 McKenna FP. What role should the concept of risk play in theories of accident involvement? *Ergonomics* 1988;31:469–84.
- 36 Wilde GJS. Accident countermeasures and behavioral compensation—the position of risk homeostasis theory. *Journal of Occupational Accidents* 1989;10:267–92.
- 37 McKenna FP. In defense of conventional safety measures: a reply to GJS Wilde. *Journal of Occupational Accidents* 1990;11:171–81.
- 38 Evans L. Risk homeostasis theory and traffic accident data. *Risk Analysis* 1986;6:81–94.
- 39 Wilde GJS. Notes on the interpretation of traffic accident data and of risk homeostasis theory: a reply to L Evans. *Risk Analysis* 1986;6:95–101.
- 40 Evans L. Comments on Wilde's notes on "Risk homeostasis theory and traffic accident data." *Risk Analysis* 1986;6:103–7.
- 41 Wilde GJS. Risk homeostasis theory: an overview. *Inj Prev* 1998;4:89–91.
- 42 O'Neill B, Williams A. Risk homeostasis hypothesis: a rebuttal. *Inj Prev* 1998;4:92–3.
- 43 Adams JGU. *Risk and freedom: the record of road safety regulation*. Cardiff, Wales: Transport Publishing Projects, 1985.
- 44 Adams JGU. *Risk/John Adams*. London: UCL Press, 1995.
- 45 Mackay M. Seat belt use under voluntary and mandatory conditions and its effect on casualties. In: L Evans, RC Schwing, eds. *Human behavior and traffic safety*. New York, NY: Plenum, 1985: 259–78.
- 46 Department of Transport. *Compulsory seat belt wearing*. London: HMSO, 1985.
- 47 Irwin A. Technical expertise and risk conflict—an institutional study of the British compulsory seat-belt debate. *Policy Sciences* 1987;20:339–64.
- 48 Adams JGU. Smeed's Law, seat belts and the emperor's new clothes. In: Evans L, Schwing RC, eds. *Human behavior and traffic safety*. New York, NY: Plenum, 1985: 193–248.
- 49 Evans L. *Traffic safety and the driver*. New York, NY: Van Nostrand Reinhold, 1991.
- 50 Evans L, Schwing RC, eds. *Human behavior and traffic safety*. New York, NY: Plenum, 1985.
- 51 Brown I, Janssen W, eds. Risky decision-making in transport operations. *Ergonomics* 1988;31:405–669.
- 52 Trimpop RM, Wilde GJS, eds. *Challenges to accident prevention: the issue of risk compensation behavior*. Groningen, Netherlands: Styx Publications, 1994.
- 53 Stanton N, Glendon I, eds. Risk homeostasis and risk assessment. *Safety Science* 1996;22:1–262.
- 54 Viscusi WK, ed. Product safety and managerial decisions. *Managerial and Decision Economics* 1996;17:437–530.
- 55 Organization for Economic Co-operation and Development. *Behavioural adaptations to changes in the road transport system*. Paris: OECD, 1990.
- 56 Adams JGU. Risk homeostasis and the purpose of safety regulation. *Ergonomics* 1988;31:407–28.
- 57 O'Neill B, Lund AK, Zador P, et al. Mandatory belt use and driver risk taking: an empirical evaluation of the risk compensation hypothesis. In: Evans L, Schwing RC, eds. *Human behavior and traffic safety*. New York, NY: Plenum, 1984: 93–107.
- 58 Sagberg R, Fosser S, Saetermo I-AF. An investigation of behavioural adaptation to airbags and antilock brakes among taxi drivers. *Accid Anal Prev* 1997;29:293–302.
- 59 Rivara FP, Thompson DC, Beahler C, et al. Systematic reviews of strategies to prevent motor vehicle injuries. *Am J Prev Med* 1999;16:1–5.
- 60 Wagenar AC. Importance of systematic reviews and meta-analyses for research and practice. *Am J Prev Med* 1999;16:9–11.
- 61 Evans L. Human behavior feedback and traffic safety. *Human Factors* 1985;27:555–76.
- 62 General Accounting Office. *Highway safety: motorcycle helmet laws save lives and reduce costs to society*. Washington, DC: US General Accounting Office, 1991.
- 63 Muelleman RL, Minek EJ, Collicot PE. Motorcycle crash injuries and costs: effect of a re-enacted comprehensive helmet use law. *Ann Emerg Med* 1991;21:266–72.
- 64 Fleming HS, Becker ER. The impact of the Texas 1989 motorcycle helmet law on total and head-related fatalities, severe injuries, and overall injuries. *Medical Care* 1992;30:832–45.
- 65 Kraus JF, Peek C, McArthur DL, et al. The effect of the 1992 California motorcycle helmet usage law on motorcycle crash fatalities and injuries. *JAMA* 1994;272:1506–11.
- 66 Viscusi WK. Consumer behavior and the safety effects of product safety regulation. *Journal of Law and Economics* 1985;28:527–54.
- 67 Magat WA, Moore MJ. Consumer product safety regulation in the United States and the United Kingdom: the case of bicycles. *Rand Journal of Economics* 1996;27:148–64.
- 68 Rodgers GB. The safety effects of child-resistant packaging for oral prescription drugs. *JAMA* 1996;275:1661–5.
- 69 Assargård U, Sjöberg G. The successful introduction of child resistant closures for liquid paracetamol preparations. *Safety Science* 1995;21:87–91.
- 70 Viscusi WK, Cavallo G. Safety behavior and consumer responses to cigarette lighter safety mechanisms. *Managerial and Decision Economics* 1996;17:441–57.
- 71 Alexander DL. An empirical investigation of lawn-mower safety regulation. *Applied Economics* 1990;22:795–804.
- 72 Moore MJ, Magat WA. Labeling and performance standards for product safety: the case of CPSC's lawn mower standards. *Managerial and Decision Economics* 1996;17:509–16.
- 73 Viscusi WK. The impact of occupational safety and health regulation, 1973–1983. *Rand Journal of Economics* 1986;17:567–80.
- 74 Lanoie P. Government intervention in occupational safety—lessons from the American and Canadian experience. *Canadian Public Policy* 1992;18:62–75.
- 75 Klen T. Personal protectors and working behavior of loggers. *Safety Science* 1997;25:89–103.
- 76 Glendon AI, Hoyes TW, Haigney DE, et al. A review of risk homeostasis theory in simulated environments. *Safety Science* 1996;22:15–25.
- 77 Jackson JSH, Blackman R. A driving-simulator test of Wilde's risk homeostasis theory. *Journal of Applied Psychology* 1994;79:950–8.
- 78 Tenner E. *Why things bite back: technology and the revenge of unintended consequences*. New York, NY: Random House, 1996.