*Behavior and Social Issues, 17,* 139-160 (2008). 

# BICYCLIST AND MOTORIST ENVIRONMENTS: EXPLORING INTERLOCKING BEHAVIORAL CONTINGENCIES

Joseph C. Dagen & Mark P. Alavosius[1]
*University of Nevada, Reno*

ABSTRACT: This paper argues that collisions between bicyclists and motorists are the result of faulty interlocking contingencies. This theoretical assertion suggests the need for dedicated evaluation methods, tools, and data systems sensitive to relevant behavioral variables operating at multiple analytical levels. Suggestions are made for creating and aligning a research agenda tailored to bicyclist safety in the context of these interlocking contingencies.
KEYWORDS: pedestrian safety, cultural change, interlocking behavioral contingencies.

This paper considers how applications of behavior analysis at both cultural and individual levels can impact bicycle collisions and injury prevalence by examining and aligning linkages among contingencies affecting individual behavioral repertoires and cultural practices. We examine individual and cultural contingencies as they contribute to understanding how linking large-scale initiatives to individual behavior change could be accomplished. Recommendations are made for aligning current contingencies and building additional contingencies to support safety-related behaviors. We also examine potential behavioral targets and their contribution to injury as revealed by the measurements used across behavior management systems.

An appropriate account of the behavioral processes at various levels can inform attachment points for behavior analysis and future research agendas. Planned cultural change might occur by systematically altering molar contingencies whose effects cascade to the level of the individual; in practice, however, this effect is difficult to orchestrate and not seen routinely. Building data systems sensitive at both the process and outcome levels may assist in promoting cultural change.

[1] The authors may be contacted at: joe_dagen@yahoo.com and malavosius@aol.com.

## BICYCLE USE AND INJURY

### *Popularity*

Bicycling has been pushed into mainstream America by multiple factors. Media reports of Americans' success in road racing (e.g., the Tour de France), rising fuel costs, and renewed emphasis on fitness all likely contribute. The sales boom in road bicycles from 2003-2005 offers some evidence of this cumulative effect. Suppliers and retailers recorded a 21% growth rate in sales from 2003-2004 that was eclipsed by a 32% gain from 2004-2005 (Wiebe, 2006).

The Bicycle Product Suppliers Association (BPSA) recorded an increase of 18.6% in total sales from 2003-2005; a growth rate of 9% from $588 million to $697 million. Adding non-BPSA retailers to total market sales moves the gross estimate to approximately $1.4 billion in 2005. The National Sporting Goods Association forecast the total monetary value of the US bicycle industry at $5.9 billion for 2005, representing $600 million and $200 million gains from 2003 and 2004 respectively.

### *Benefits*

As an outstanding product of the industrial revolution, the bicycle offers tremendous health and transportation benefits for individuals and communities. Bicycling promotes physical health and acts as a clear combatant in the war against obesity. The 2005 CDC estimates offer shocking evidence of the widespread obesity crisis in the US. Only four states maintain obesity prevalence (defined as a Body Mass Index > 30) lower than 20%, while 17 states maintain obesity prevalence above 25%. It should be noted that in 1985, 13 states reported obesity prevalence lower than 10%. No states currently fall below 15%. In 2005, Colorado, Connecticut, Hawaii, and Vermont maintained the lowest obesity prevalence at 15-19% (Centers for Disease Control, n.d.). Obesity in the US is clearly a public health disaster and severely strains the overworked and understaffed health-care system. Consistent physical exercise like that provided by daily bicycling could substantially ameliorate these obesity statistics.

As the cost of crude oil rises, consumer behavior regarding transportation choices may change. Such choices are not random events but reflect behavior under the influence of complex factors (Foxall, 2003). Preference for expensive SUV's is shifting to less fuel-thirsty alternatives as vehicle characteristics, branding, competitive cost advantage, advertising, incentives and probably other influences drive consumers towards more efficient modes of transport. Hybrids,

public transportation and bicycling become more economically sensible modes of transportation and may become more preferred.

The bicycle offers a cost-effective mode of transportation, producing no pollution, removing the need for vast parking facilities, and consuming no natural resources in operation. Large cities would reap substantial financial and environmental benefits from increasing bicycling-based transportation systems. Indeed, the adoption of cycling for transportation is widespread, as every day approximately 500,000 US citizens commute to work via a bicycle (Reschovsky, 2004). Increasing the number of commuting bicyclists could decrease the strain on congested city roadways, and likely occasion others to adopt this technology.

### *Cost*

Bicyclist injuries and fatalities are a serious problem that is likely to increase as more people adopt this mode of travel. Collisions between bicyclists and motorists due to human error are strong contributing factors to the injury and fatality prevalence. Bicycling and driving on the same roadway creates a complex environment in which minor behavioral variability can create catastrophic outcomes. Ideally motorists travel safely in their designated lanes and bicyclists travel safely in their designated lanes and the two never make contact. As each travels down the road, however, differing levels of variability exist in their behavior. Specifically, while motorists and bicyclists generally stay in their respective lanes, occasionally one may drift into another and a close-call or collision occurs.

Since 1932, more than 49,000 bicyclists have died in traffic collisions in the US. Although the greatest number of deaths recorded occurred in 1975 (1,003), the most recent count (784 total deaths in 2005, 720 from crashes with motor vehicles) represents the typical rate of bicycling fatalities. Florida maintains the highest death rate among bicyclists at 7.01 deaths per million population followed closely by Nevada and Hawaii with 6 deaths per million and 5.54 deaths per million, respectively. Interestingly, Rhode Island, home of the Narragansett Bay Wheelmen – the oldest bicycling club in America, and Wyoming recorded no bicycling related deaths in 2004 (Johns Hopkins Prevention Center, n.d.; National Highway Traffic Safety Administration, 2004).

People make approximately 1.8 billion bicycling trips per year, with approximately one death every two million trips nationally. These data are difficult to interpret as the length and duration of a "trip" are unknown but do provide a crude index. Approximately 20,000 bicyclists in the US are admitted to hospitals annually, while 580,000 bicyclists receive emergency room treatment. Motor vehicles are involved in 90-92% of the bicycling fatalities, but only 12% of

bicycling injuries (Johns Hopkins Prevention Center, n.d.). Unsurprisingly, these data suggest the deaths of bicyclists result from interactions between bicyclists and motorists in a shared road space.

Estimates of accidental fatalities, injuries, and close-calls provide a profile of the problem. For every death, safety professionals estimate there are hundreds of serious injuries. For every serious injury there are many minor injuries and hundreds of at-risk behaviors (Heinrich, 1931). From the reported number of deaths and injuries, we can be confident there is a vast reservoir of risky behaviors ready to combine and yield catastrophic outcomes, and this reservoir will, more likely than not, expand.

### *Complexity of Bicycling Behavior*

Operating a bicycle involves a complex series of behaviors that must be executed with correct precision and timing. As evident by any child first learning to ride a bike, bicycling is difficult to learn. This behavior must necessarily come under the control of additional environmental stimuli as the skill level of the bicyclist increases. Pavement markers, crosswalks, fatigue, weather, road conditions, other bicyclists, etc. all occasion variable bike-handling behavior.

Different bicyclists eventually develop and possess different behavioral repertoires, depending on the function of their bicycling behavior—commuting, recreation, fitness, and racing. For example, a business worker commuting to work is responding to the same general set of stimuli as a competitive racing bicyclist, but possesses a different behavioral repertoire with regards to those stimuli. A commuting bicyclist and a fitness bicyclist approaching the same intersection as the traffic signal changes from green to yellow may respond differently. To commuting bicyclists, the light change will likely function to prompt braking resulting in the bicyclist stopping before the light changes to red. The same stimulus may function as a challenge for the competitive fitness bicyclists; they may increase their speed in an attempt to "beat" the impending red light. These fitness bicyclists find the behavior of stopping highly aversive because of various accompanying conditions (e.g., decreased heart-rate, lost momentum, etc). Thus the effects of roadway stimuli on bicyclist behavior are not universal.

The bicyclist may also be fatigued by the exertion of cycling, thus affecting relevant variability. The bicyclist must discriminate between different directions of traffic and possible turning vehicles while watching for road debris and adjusting the direction of travel to avoid impediments. Powerful stimuli may bombard the bicyclist such as strong winds, traffic noise, and physical feedback

from the bicycle. With these additional stimuli present, a vehicle turn signal may not be salient enough to control the bicyclist's behavior.

Relevant bicycling safety behavior may also be highly variable. For example, appropriate signaling for turning or changing lanes varies with road conditions, environmental hazards, speed, the bicyclists' learning history, etc. Under these various conditions, bicyclists may not remove their hand from the handle bar to signal their turning intentions. Without these signals from bicyclists, motorists' ability to predict bicyclists' behavior decreases; inversely affecting the probability of a collision or close-call.

### *Complexity of Driving Behavior*

Motorists likewise develop complex behavioral repertoires under the control of fine-grained stimuli distinctions. Developing this repertoire successfully requires years of driving, as evidenced by the crash statistics of young drivers. The use of graduated licenses has been a remarkably successful technique for teaching these young drivers appropriate skills under varying degrees of supervision (Falb, 2005). However, in cities lacking graduated driver license programs, the skill level achieved by young drivers may not reach expert competence before these drivers are operating in the same environment as similarly novice bicyclists.

Although there may be loud music and feedback from the vehicle, the interior of a vehicle is a contained, highly controlled environment. The designer of the automobile arranges the stimuli impinging on the driver for maximum safety and comfort. The bicyclist is exposed, however, to much more uncontrolled and unpredictable stimuli. The motorist has much less direct experience of their speed, momentum, and road conditions than bicyclists. The bicyclist is immersed in the ongoing conditions of the road environment. Additional stimuli like cell phones only add to the complexity of driving behavior.

### *Motorist and Bicyclist Variability*

Behavioral variability within these two agents is radically different. For example, motorist steering variability is reduced through the vehicle's mechanics and is not transmitted directly to the road. Gross changes in direction require large, gross motor movements (i.e., turning the steering wheel ten degrees does not produce a ten degree change in the tires). Additionally, motor vehicles are constructed to reduce feedback to the motorist (i.e., suspension to eliminate bumps, insulation to reduce audible noise, etc).

Small variability in the bicyclists' steering behavior produces a direct and equivalent corresponding change in the direction of travel. There are no

mechanisms within the bicycle to reduce the impact of slight body movements on the operation and direction of the bicycle. The handlebars turn in unison with the wheels, instead of the reduction mechanism within automobiles. Thus, the bicyclist is required to attend to body position and features of the road more closely than motorists, as minor variations produce dramatic consequences.

### *Safety Features*

It is provocative to consider how safety advances to mediate one class of injuries may have unintentional consequences creating more risk for other classes of injuries. While the bicycle design has changed very little with regard to safety over the past one hundred years, the automobile has been continually refined. As the automobile technology advances, there are corresponding changes in driver behavior. Consider a hypothetical SUV that produces an audible alarm when backing up in close proximity to another object. This well-intentioned safety feature may have behavioral consequences of extinguishing appropriate spatial discrimination behaviors for drivers. It should be noted that bicycling manufacturers have focused almost exclusively on personal protective equipment (PPE) for safety. Relatively limited technological advancements for safety such as reflectors and lights exist, but are typically optional devices and not routinely utilized.

### *Interactions between Motorists and Bicyclists*

The bicyclist is a variable feature of the driver's environment. Many motorists have no experience with bicycling and cannot accurately predict bicyclists' behavior. This is complicated by the variations in bicycling behavior as a function of their purpose in bicycling. As previously discussed, individual bicyclists are displaying similar response classes, but responding differentially to environmental stimuli. Those bicycling for transportation are primarily interested in safety and comfort, whereas those interested in fitness may be primarily interested in speed, handling, and the quality of the workout. As these represent different response classes, they may occasion different reactions by motorists.

For example, consider the effects of these different visual stimuli (the commuting bicyclist vs. the fitness bicyclist) with respect to driver behavior. One group of bicyclists may be stigmatized based on their visual appearance (e.g., fitness riders wearing racing regalia and helmets), and some motorists actually respond aggressively by swerving toward these riders (Walker, 2007). Other bicyclists (e.g., children, commuters) appear more vulnerable and are treated with caution as motorists swerve away.

Multiple researchers have demonstrated conditioned stigmatization effects similar to those demonstrated by Walker (2007) in a variety of contexts (Dixon, Dymond, Rehfeldt, Roche, & Zlomke, 2003; Hayes, Niccolls, Masuda, & Rye, 2002; Staats & Staats, 1958). In this regard, the expert status produced by hours of dedicated training coupled with the appearance of an elite athlete may only serve to make bicyclists and motorists less safe. Additional work is needed to explore the stigmatization of bicyclists in relation to specific learning histories, and how to alter these stigmatization effects.

Research investigating risk compensation behavior may also be valuable to the present analysis (Streff & Geller, 1988; Wilde, 1994). Risk compensation suggests that as the perceived safety of an environment or activity increases, safety behavior decreases. The data produced in Walker (2007) demonstrating that motorists drive significantly closer to bicyclists wearing helmets is predicted by this model. Thus, as advances occur in both automotive design and PPE for bicyclists, injury prevalence may remain stable. Targeting motorists' and bicyclists' behavior directly offers a potential solution to this inverse relationship. This is not to suggest behavioral solutions replace PPE, but rather that both behavioral and technological components must be addressed to promote effective behavior change.

### *Context of Injury*

Bicyclists and motorists share the roadway. Injury occurs when one of these physical entities makes contact with the other. The context of the injury is the shared environment immediately preceding the physical contact. The motorist's immediate environment, as previously discussed, is highly controlled and predictable, whereas the bicyclists' environment is not as well controlled and not as predictable. Ideally, the environments of motorists and bicyclists would remain separate, as depicted in Figure 1. In most US cities, however, significant overlap exists between the motorists' environment and the bicyclists' environment, as shown in Figure 2. It is within this shared context that injuries and fatalities occur.

Communities presumably accept some prevalence of injuries and fatalities as inherent in the shared context of motorists and bicyclists. If the prevalence remains below the accepted community standard, intervention and or separation of environments may not be selected. However, as injuries and fatalities increase, increased media attention, advocacy mandates, and local legislation occur, eventually leading to partial or complete separation of motorist/bicyclist environments. Thus, there exists a fluctuating tipping point at which the number of injuries and fatalities of bicyclists will necessitate removing them from the roadway (Gladwell, 2002). This point is shifted however by other factors such as

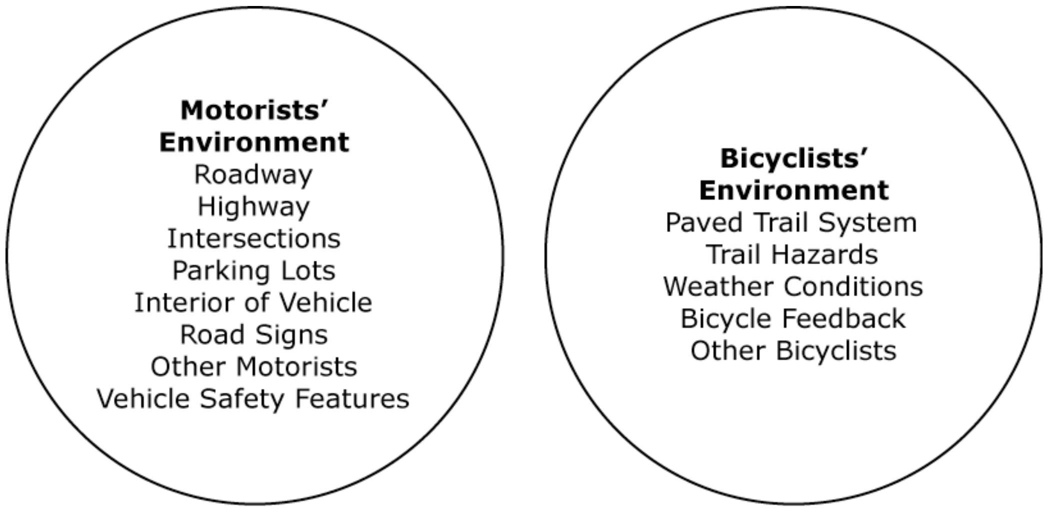


*Figure 1. Ideal Separation of Environments.*

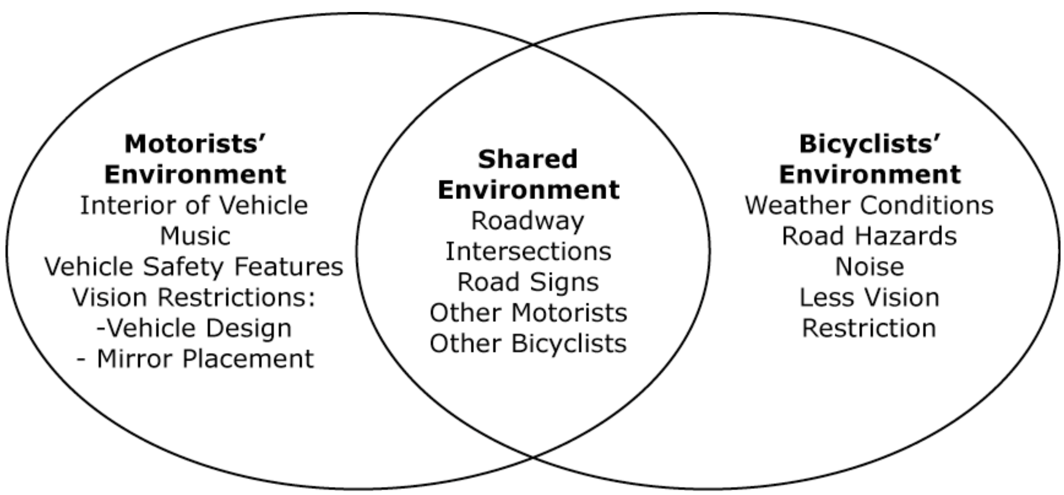


*Figure 2. Current overlap of environments.*

fuel prices, parking limits, congestion, and environmental concerns that promote adoption of bicycles as a preferred mode of transportation.

Environmental engineering offers one approach to injury and fatality prevention. By removing the overlap between these environments, the context for bicycle collisions with motor vehicles is removed. However, the cost of such an environmental solution (i.e., removal of all bicyclists from roadway by building appropriate bike paths or building a cement median instead of painted bike lanes) is excessive. Further, partial separation may occasion increased risky behavior as predicted by the risk compensation literature. Behavioral solutions, however, do not require separation of environments, high costs associated with large-scale environmental engineering, or produce an increase in alternative risky behaviors. Rather than remove bicyclists from the roadway, examining behavioral contributions to injuries and fatalities could inform a research agenda and prescribe antecedents/consequences to increase the occurrence of safe behavior and decrease the occurrence of risk behavior.

Because of the shared environment between bicyclists and motorists, molecular behavior analytic solutions are unlikely to succeed without integration into a molar systems analysis that includes both types of transportation. Given that both modes of transportation share the same roadway, it is not surprising the many sources of behavioral variability interact and result in conflict. What is clear is that the behavior of bicyclists and motorists interact in a complex environment with the results being unpredictable when only one agent is considered independent of the other.

## GOVERNMENT ACTION

### *Historical Precedence*

High injury and fatality rates arising from interactions of complex behavioral phenomenon may eventually occasion large-scale government responses to motivate cultural change. Many occupational safety regulations and sanitation mandates resulted from a high prevalence of injuries and fatalities, occasioning the government to adopt regulations and standards that affect cultural practices. For example, the high injury and fatality rates in high-risk industries occasioned the creation of the Occupational Safety and Health Organization (OSHA) in 1971 whose regulations have reduced hazards, controlled exposure to harmful chemicals, and improved safety in many industries. With the advent of OSHA, organizational cultures have shifted to an emphasis on employers' compliance with safety standards maintained by avoidance of penalties. Today, mandated OSHA standards are an accepted additional cost of doing business in the US.

It should be noted that penalizing companies for non-compliance with written standards establishes rule-governed behavior via negative reinforcement. Multiple researchers in the basic, applied, and philosophical domains of behavior analysis and applied behavior analysis have debated the potential merit of positive and negative reinforcement for behavior-change procedures (Baron & Galizio, 2005; Malott, 2002; Michael, 1975; Sidman, 2006; Skinner, 1950). Although effective, negative reinforcement procedures produce problematic ancillary consequences such as avoidance and escape not inherent in positive reinforcement procedures. Witness the transfer of many manufacturing jobs from the US to less regulated countries as employers seek to escape the high costs of labor in this country in part due to higher safety standards. Embracing positive reinforcement to produce cultural change rather than negative reinforcement is perhaps technically more challenging especially when the desired benefits are delayed but allows a greater probability of sustained success and avoids unintended consequences (Argyris, 1968).

For example, behavior-based safety (BBS) has been extremely successful by arranging positive reinforcement contingencies to drive safety-related behavior (Geller, 2001, 2005; Krause, Hidley & Hodson, 2001; McSween, 2003; Sulzer-Azaroff, 1978). Although the specific features of each BBS system and intervention vary, most are typified by direct observation, immediate feedback, training, goal setting, and incentives. For a more detailed review of BBS and its effectiveness, see Sulzer-Azaroff & Austin (2000).

The process of governmental action filtering down via legislative mandates is slow, and rarely are ideal mandates created and refined before the culture selects them. The process includes competing contingencies, more immediately reinforcing temporary solutions, and resistance from those affected by aversive consequences of the mandates (e.g., witness the current resistance to OSHA ergonomic standards). The rate of bicycling injuries and fatalities has not yet reached the tipping point nationally to occasion cultural change via governmental response like what occurred with occupational injuries, seat-belt laws, drunk driving, smoking or many other cultural changes directed by community conglomerates pressuring successfully for governmental response.

To date, there have been no culture-changing governmental actions to bicycling injuries/fatalities, but large-scale governmental responses are beginning to surface as more individuals begin bicycling and close-call/injury rates become more salient. Eventually, practices derived from local or regional solutions may be selected as cultural practices. The previously mentioned factors suggest the pressure for action is building and will inevitably demand intervention.

### *Advocacy Groups*

Multiple interdisciplinary groups, both at the local and national levels, have formed with primary interests of decreasing bicycling injuries and fatalities (Federal Highway Administration Bicycle and Pedestrian Program, The National Center for Bicycling and Walking, The National Highway Traffic Safety Administration, the Surface Transportation Policy Project, the League of American Bicyclists, and the Bicycle Helmet Safety Institute). These groups advocate for safety education, increased funding for bicycling-related projects, and attempt to align community bicycling initiatives with larger-scale government initiatives.

Given stable injury and fatality rates a clear disconnect exists, however, between bicycling-related intervention strategies and the number of advocacy groups and corresponding governmental dollars spent on the problem. Data pertinent to assessing the effectiveness of group initiatives in changing individual at-risk behaviors do not emerge from current monitoring and reporting systems. Further, the data do not function at different levels of analysis within the current organizational system. For example, there are no existing links between bicycling club data, insurance industry data, city and state data, and corresponding initiatives and solutions aimed at decreasing bicyclist injuries and fatalities.

Interventions to improve the safety of bicyclists continue to surface, however. Consider a recent bill in Ontario, Canada, to remove bicycles, helmets, and lights from retail sales tax. The legislation aims to promote bicycling and bicycle safety, yet there has been little discussion regarding what data will be used to monitor the effects of these interventions. In light of demonstrations that wearing a helmet may occasion close driving behavior by motorists, it would seem that even well meaning interventions may have unintended consequences (Walker, 2007; Wilde, 1994).

### *Data-Based Initiatives*

Informed governmental policy must come from data sensitive to ongoing behavioral and environmental contributions to injuries and fatalities. Data systems developed for different problems are unlikely to capture the wealth of detail needed for a useful functional assessment of bicycling fatalities. For example the chemical industries (e.g., volatile gases) have well-developed detection and surveillance systems to measure important variability that can cause catastrophic accidents. These systems have benefited from a long development period within relatively constrained industrial environments. They function reasonably well in those specific contexts, and may provide a model for those seeking to build a

bicycling data system. These data systems cannot be replicated without modification to measure the sources of variability relevant to bicycling and driving.

Functional data for bicycling related injuries and fatalities consist of environmental and behavioral components for both motorists and bicyclists. For example, bicyclist environmental conditions consist of: weather, time of day, road debris, complexity of road design, potential equipment failure, ancillary stimuli (iPods, etc), speed, lighting, drug consumption, and traffic volume. Bicyclist behavioral data consist of: variability in road position, handling, braking, signaling, and responding to traffic and motorist signals. These behavioral components can then be broken into their component features (duration, latency, topography, intensity, etc) for a full functional analysis. A similar analysis of environmental events and behavioral components for motorists provides the complete dataset of interest; noting that some components (cell phone usage for example) are far more prevalent in one agent (motorist or bicyclist) than the other. Motor vehicles and bicycles are increasingly equipped with instrumentation to record these variables; more are needed.

Armed with appropriate data, relevant agencies can band into influential conglomerates and create powerful social contingencies for safety-related behavior. For example, bike manufacturers, advertisers, media, school systems, and sports celebrities currently can collaborate to promote safe-bicycling behavior. Bicycling occurs in public roadways, yet the proficiency of the individual cyclist is often a function of unique childhood learning histories with little influence from formal organizations.

## A Framework for Reform

### *Behavior Analysis*

While traditional views maintain that unintentional injuries are the result of random, uncontrollable events, behavioral psychologists have long viewed injuries as the complex interactions between individuals and their environments (Sulzer-Azaroff, 1978). From this paradigm, analyses focus on relations between environmental and behavioral events rather than hypothetical mental traits.

Interlocking behavioral contingencies (IBCs) are defined as contingencies in which the behavior or behavioral product of one individual acts as the antecedent for another individual's behavior and the consequences for both individuals are shared (Glenn & Malott, 2004). For example, when one office worker A, organizes a client file for another office worker B to input into a database, their

behaviors are interlocked in that the behavioral product of worker A (the prepared file), acts as the antecedent for worker B.

Researchers from a variety of related fields are examining various conditions and effects associated with bicycling injuries (Lajunen, & Rasanen, 2004; Legg, Laurs, & Hedderley, 2003; Ortega, Shields, & Smith, 2004). Not surprisingly, most of these studies focus on attitudes and beliefs rather than the behavior of individuals. While multiple studies exemplify this pattern of appealing to hypothetical mental traits or characteristics to explain, predict, or control behavior, practical and effective interventions require manipulation of relevant antecedent or consequent variables to select behavior change.

Some researchers demonstrate misconceptions about behavior analysis by likening behavioral theory to expectations, skills, and beliefs (Thompson, Sleet, & Sacks, 2002). These researchers (Thompson et al.) reviewed 109 articles relating to bicycle helmet use and cycling behavior. Their discussion focuses on predisposing factors, enabling factors, and reinforcing factors related to bicycle helmet use by children. The authors recommend targeting knowledge, attitudes, and beliefs with limited reliance upon contingencies of reinforcement. They conclude people are at different stages of readiness to wear helmets and suggest adoption of safety gear is a function of uncontrollable, non-environmental factors.

### *Transcending Localized Solutions*

Working from a behavioral approach allows pragmatic analyses and intervention while maintaining a high degree of social validity. This approach has produced remarkably successful results over the previous 40 years (Grindle, Dickenson, & Boettcher, 2000; Kulik, & Cohen, 1979; McAfee & Winn, 1989). While the majority of injury/illness behavioral studies have focused on occupational settings, a small but growing subfield has been evaluating pedestrian safety concerns (Austin, Hackett, Gravina, & Lebbon, 2006; Boyce & Geller, 2002; Huybers, Van Houten, & Malenfant, 2004; Miller, Austin, & Rohn, 2004; Van Houten, 1988; Van Houten, & Malenfant, 2004; Van Houten, Malenfant, Zhao, Ko, & Van Houten, 2005; Van Houten & Retting, 2001).

These studies are a positive step forward, but they typically address isolated behaviors and interventions without direct tests of supports needed for community-wide adoption. For example, Austin et al. (2006) evaluated the effects of prompting and feedback signs for drivers' stopping behavior at two opposing intersections. The independent variable was a volunteer displaying a prompting sign for the motorist to stop. The volunteer turned the sign over displaying a feedback message if the driver behaved appropriately to the initial stop prompt. The data demonstrated that prompting and feedback produce significant

differences in the number of driver stopping behaviors. The authors point out the difficulty inherent, however, in wide-scale adoption of such labor-intensive procedures: high costs associated with human sign holders.

Studies of localized solutions are valuable as they provide elements that can be built into functional cultural solutions. For example, researchers have identified individual behavior-change elements that can promote procedural maintenance after the completion of programmed intervention. Siggurdsson and Austin (2006) analyzed the inclusion and effects of four institutionalization variables across 11 years of organizational studies. The four variables were: 1) involvement in design, 2) training of internal staff, 3) formal data collection system and, 4) formal system of dispensing consequences. Results suggest that programming these variables increases both the effectiveness and maintenance of interventions. While the exclusionary criteria for their review necessarily removed systemic interventions from their analysis, these institutionalization variables may promote adoption and maintenance of systemic interventions through rule-governed behavior. While it is assumed programming these variables at the level of individual behavior change procedures will supplement wide-scale adoption of cultural interventions, research is needed to assess the interaction of these variables in larger contexts.

### *Cultural Best Practices*

Davis, California is considered to be the most bicycle friendly city in the US with approximately 20% of city trips made by bicycle (US Department of Transportation, 1998). The US Department of Transportation report of best practices related to bicycling in exemplary cities points to technological advances in bicycle-specific traffic signals and signal timing as unique and beneficial safety features of that city. These traffic signals utilize specially made bicycle symbols and allow an extra 30-second bicycle-only traffic phase—thus reducing the possibility of conflict while a bicyclist transverses the intersection. Thus, they employ specifically designed signage to occasion safety behavior at critical intersections (see Van Houten & Retting, 2001, for a similar technology).

While the innovations discussed in the Federal Highway Administration report may function to decrease collisions/injuries, evidence is lacking that exemplary cities demonstrated decreases in collisions/injuries *because* of those initiatives and best practices. Systematic evaluations and refinement of these best practices are not described, and it is unclear what data are used for testing. As Biglan (1995) has pointed out, we must examine the conditions under which those communities adopted best safety practices.

Organizational researchers have developed multiple *theoretical* models that attempt to bridge different levels of analysis; the A-B-C model and The Total Performance System for example (Brethower, 1982; Daniels, 1989). These models are useful for mapping and managing the internal operations of complex organizations and linking process improvements to desired outcomes (e.g., products). They may offer initial stepping-stones toward developing a technology of planned cultural change that includes technical models for measuring interconnected dimensions of layered contingencies. However, leadership is needed to design contingencies and data systems that establish methods to trouble-shoot the networked contingencies that comprise a planned culture. Once a network model is established, as described in *Walden Two* (Skinner, 1948), the community sustains practices and improves upon them. Leadership is less necessary as the contingencies and data maintain organized practices. For a more complete review of organizational models bridging different levels of analysis, see Austin (2000).

Networked models are also being proposed in provocative analyses of cultural practices accounting for the rapid spread of obesity and its prevention. Public health researchers (Barabasi, 2007; Christakis & Fowler, 2007) are examining the social context of obesity and developing tools to map interconnected relations in social and biological networks. These investigations expand the purview of medical interventions to include consideration of social and communication networks in combating public health problems like obesity, influenza, and other phenomena characterized by contagious spread. Behavior analysts might look to advances in these disciplines and seek to systematically replicate technologies for assessing complex, dynamic networks.

### *Advocacy Reform*

From a molar perspective, the individual agencies dedicated to increasing bicycling safety lack power to reach all relevant sectors. Banding available agencies into more powerful and influential conglomerates may yield contingencies networking businesses, governments, and additional civic organizations. Within these comprehensive groups, practices pertinent to detecting variability in safety could be implemented and linkages continually refined as goals are met. For example, building a renewable consensus about goals, defining unbiased, widely available assessment methods, and using media to promote safety all fall into initially acceptable and measurable goals. These goals could be reviewed and updated yearly as data drive decisions by the banded advocacy groups.

Organizations and businesses could easily implement incentive systems to encourage bicycling. Workers could earn monetary rewards, time-off, and choice of work detail, contingent on bicycling to work. As organizations urge their employees to bicycle, governments could decrease relevant company taxes providing support for sustained behaviors.

Given the enormous health benefits of daily exercise, health care companies could also be integrated into this system. With access to a standardized database that tracks health-care costs, health insurance premiums could be adjusted as employees begin bicycling. This entails integrating efforts of multiple agencies (government, media, employers, insurance, manufacturers, etc.) so the contingencies are aligned to support desired practices and socially beneficial outcomes. Few behavior analysts besides Frasier (Skinner, 1948) have aspired to this level of systemic application as much effort is directed at localized solutions to relatively smaller-scale problems.

Designing a socially valid methodology for assessing improvements in motorist and bicyclist safety culture remains an unsolved and practical necessity. For researchers, community members, and policy makers to create safety goals and verify outcomes, relevant motorist and bicycling safety data must be collected and compiled into functional working databases. Pertinent information related to both motorist and bicyclist behaviors are omitted from current databases, obscuring our ability to accurately assess them. The initial step to decrease the prevalence of bicycling injury and fatalities is to develop functional data systems that allow for the detection of causal relationships among relevant variables. For example, while the databases show alcohol is related in 35% of all bicyclist/motorist collisions, information detailing how alcohol increased the variability of driving or bicycling behaviors and contributed to a collision is absent. Contextual variables are not linked to alcohol data allowing for cross tabulation or data mining.

### *Behavioral Consequences*

Multiple disconnected contingencies exist between motorists and bicyclists. For example, as bicyclists traverse intersections without assessing possible risk via accurate visual inspection, their behavior is naturally reinforced by successful continuation along the road. In this sense, the environment may reinforce risk-taking behavior by allowing uninterrupted travel absent appropriate risk assessment. The same contingency exists for the motorist—when the motorist turns from one roadway onto another without first checking for bicyclists in their direction of travel, their behavior typically results in uninterrupted continuation

along their way. These consequences of non-collision may reinforce risk-taking behavior, but severely punish collisions.

To combat these contingencies, bicyclists may create a self-watch group where individual bicyclists (commuter, recreation, and fitness) provide effective feedback and training to other group members during public bicyclist/motorist interactions. Current organized club rides are popular and approach this process. The primary goal of a proposed group would be to decrease bicycling-related behavioral variability (e.g., bicycling within lanes, using hand signals, and appropriate intersection discrimination and crossing). Erratic and risky behavior while bicycling could be corrected immediately with feedback by other bicyclists observing the problem. Public posting of at-risk behavior, close-call data, and injury data, updated regularly on community web-pages, could provide a delayed feedback measure to group members. At-risk data could be linked to embedded web-based video modules demonstrating correct and incorrect bicycling behaviors. Group members would thus learn how risky behaviors relate to close-calls and injuries and how to execute the correct alternative behaviors.

Club groups could manipulate participation fees as individual performances fluctuate. Unsafe group members, as judged by their bicycling behaviors, could pay higher fees to fund behavioral interventions. Public businesses build loyal customers by providing discounts to club members as an incentive to join the group. The level of discount could be adjusted relative to member safety status. Thus layers of immediate and delayed consequences influence safety practices and common stimuli encountered during cycling acquire stimulus control.

### *Contingency Interactions*

If the evaluation of public policy (e.g., helmet-use laws) rests on molar-level measures (collision and injury rates) understanding molecular behavioral contingencies (variability in driving/bicycling performance, stimulus generalization, consequence management, etc.) is obscured. Attention is typically placed on either molar outcomes or molecular behavioral contingencies with little consideration given to the importance of aligning data systems and selecting measures that remain functional at different levels of analysis. Disconnects in molecular contingencies can produce disastrous outcomes at the outcome level—injuries and fatalities. An ambitious agenda would be to develop technologies to measure the dynamics of interconnected relations and use data to align multi-layered contingencies discussed previously to promote safety practices.

## PRELIMINARY RESEARCH AGENDA

### *Fusing Behavior Change Technologies*

The limit of small-scale behavioral solutions to transcend to a national scale necessitates fusing the aforementioned molecular behavioral research agenda with molar behavioral systems analyses. Multiple behaviors contribute to bicyclist fatalities and injuries and this paper considered relatively few contributing factors leading to injury in the context of the shared roadway. Conceptually, the present analysis suggests the behavior of motorists and bicyclists are occurring in the same environment. Their behaviors are under the control of both overlapping and different stimuli. Thus, conflict and collisions are inevitable so long as these behaviors occur in the same space. With this framework, an appropriate research agenda should include both increasingly accurate behavioral measures and improved data systems tracking complex interactions of many individuals. The current data do not provide the level of sophistication required to functionally analyze contributing sources of variation.

A system capable of sustaining this level of programmatic research must operate on multiple analytical levels. Levels begin at the individual behavior of bicyclists and motorists and build to the level of government policy. The initial system may include analyses of individual behaviors of motorists and bicyclists and features of their immediate environments. Surveillance systems are increasing in prevalence and sophistication, allowing increased precision in detecting important sources of variation. Bicycles, like automobiles, can be equipped with sensors to measure dimensions of travel like speed, location, acceleration, deceleration, and more. Analyses of these data in light of motorist and environmental data reveal connections that can inform vehicle designers, educators, and policy makers about the impact of adjustments to their portion of the operating environment.

Functional data operate within different levels of analysis and inform the design of interlocking contingencies necessary to support the system. For example, contingencies to promote helmet use must be evaluated by considering the prevalence of complying bicyclists, the probability of close (i.e., risky) driving behavior of motorists who swerve too close, and the impact of helmet use on risky behavior. Collision and close-call data provide an outcome measure of individual behavior change contingencies. Thus, data produced at the process level may be analyzed at the outcome level.

Only within a data-based system can a research agenda be successfully evaluated. For example, consider a fictitious automotive device that automatically

records close-call data for driving in close proximity to a bicyclist. I.e., a sensor on the automobile mirror records any object within three feet of the mirror while the vehicle is in motion. At the level of individual behavior, the device may present an audible alarm prompting the driver to allow more road space for the bicyclist. Although the function of the device is at the level of individual behavior, other levels can synthesize the data into meaningful analyses. Insurance companies might collect these data and adjust premium rates contingent on safe driving behavior, using the profits from unsafe members to fund behavioral safety training. The devices could be linked to cellular technology and provide a delayed but useful feedback measure to community leaders. The data could be filtered to educators and used as an indicator of the effectiveness of driver training and intervention programs; roadway designers as measure of traffic flow; traffic police as a measure of patrol effectiveness. Available communities that support the technology might filter the data to government agencies to evaluate as a measure of government interventions such as business incentives, regulations and so on. These cascading effects can be evaluated in terms of national and community liability issues, insurance, and health care costs as the data transcend molecular analysis and remain functional indicators of intervention effectiveness at molar levels of analysis.

The creation of the National Occupational Research Agenda (NORA) in 1996 by The National Institute for Occupational Health and Safety (NIOSH) exemplifies the possibility of multi-level, systemic data collection and programmatic research. The National Occupational Research Agenda seeks to promote research in occupational safety and health through interdisciplinary goal setting and funding opportunities. With their first research agenda, NORA unveiled 21 research priorities across three different research areas: disease and injury, work environment and workforce, and research tools and approaches. Eight different occupational sectors comprised of interdisciplinary members identified the 21 research priorities, attempting to align research goals with practical goals.

While NORA does not reach the level of sophistication or integration proposed in this paper (integrating the aforementioned qualities of NORA with the health-care system, insurance systems, and related bicycling industries), it moves beyond preceding large-scale systems for systemic research and application. Individuals within NORA operate within previously established government contexts, however, which are immune to experimental manipulation. Thus, while NORA's proposed solutions are amenable to testing, the organizations under which they operate are presumably not. Data produced by NORA should inform not only the occupational health and safety realm, but

should inform refinements of both NIOSH and NORA. The inability to refine organizational systems such as NIOSH and NORA may be the greatest limiting factor to immediate and dramatic cultural change.

## CONCLUSION

Increasing fuel costs coupled with increasing obesity trends will likely occasion increased rates of bicycling. Consideration must be given to the safety of these citizens as they bicycle. Behavior analysis has predominantly been applied to isolated pedestrian safety concerns, but has demonstrated powerful behavior change technologies and informative research methods. In attempting to curtail perfunctory government responses which have historically been poorly conceived and reactive, researchers must begin creating the systems and interlocking contingencies necessary to support wide scale adoption of cultural practices. This paper is one attempt to promote discussion regarding the feasibility of creating more powerful community and government conglomerates and designing the interlocking contingencies and functional data systems to power them.

## REFERENCES


Argyris, C. (1968). Some unintended consequences of rigorous research. *Psychological Bulletin, 70,* 185-197.

Austin, J. (2000). Performance analysis and performance diagnosis. In J. Austin & J.E. Carr (Eds.), *The Handbook of Applied Behavior Analysis.* (pp. 449-472). Reno, NV: Context Press.

Austin, J., Hackett, S., Gravina, N., & Lebbon, A. (2006). The effects prompting and feedback on drivers' stopping at stop signs. *Journal of Applied Behavior Analysis, 39*, 117-121.

Barabasi, A. (2007). Network medicine: From obesity to the 'diseasome'. *The New England Journal of Medicine, 357,* 404-407.

Baron, A., & Galizio, M. (2005). Positive and negative reinforcement: Should the distinction be preserved? *The Behavior Analyst, 28,* 85-95.

Biglan, A. (1995). *Changing cultural practices: A contextualist framework for intervention research*. Reno: Context Press.

Boyce, T, & Geller, S. (2002). An instrumented assessment of problem behavior and driving style: Do younger males really take more risks? *Accident Analysis & Prevention, 34*, 51-64.

Brethower, D. M. (1982). The total performance system. In R. M. O'Brien, A. M. Dickenson, & M. P. Rosow (Eds.), *Industrial behavior modification* (pp. 359-369). New York: Pergamon Press.

Centers for Disease Control. (n.d.). Obesity trends among US adults between 1985 and 2004. Retrieved January 10, 2007, from http://www.cdc.gov/nccdphp/dnpa/obesity/trend/maps/obesity_trends_2005.pdf

Christakis, A., & Fowler, J. H. (2007). The spread of obesity in a large social network over 32 years. *The New England Journal of Medicine, 357,* 370-379.

Daniels, A. C. (1989). *Performance management.* Tucker, GA: Performance Management Publications.

Dixon, M., Dymond, S., Rehfeldt, R., Roche, B., & Zlomke, K. (2003). Terrorism and relational frame theory. *Behavior and Social Issues, 12*, 129-147.

Falb, S. R. (2005). Graduated drivers license. Iowa's experience since the law's inception. Research and Driver Safety Analysis, Iowa Department of Transportation, November. Retrieved January 15, 2007, from http://www.dot.state.ia.us/mvd/ods/gdlstudy.pdf.

Foxall, G. R. (2003). The behavior analysis of consumer choice: An introduction to the special issue. *Journal of Economic Psychology, 24*, 581-588.

Geller, E. S. (2001) *The psychology of safety handbook*. New York: Lewis Publishers.

Geller, E. S. (2005) *People based safety: The source*. Virginia Beach, VA: Coastal Training Technologies Corp.

Gladwell, M. (2002). *The tipping point: How little things can make a difference*. Boston: Back Bay Books.

Glenn, S. S., & Malott, M. M. (2004). Complexity and selection: Implications for organizational change. *Behavior & Social Issues, 13,* 89-106.

Grindle, A. C., Dickenson, A. M., & Boettcher, W. (2000). Behavioral safety research in manufacturing settings: A review of the literature. *Journal of Organizational Behavior Management, 20*, 29-68.

Hayes, S. C., Niccolls, R., Masuda, A., & Rye, A. (2002). Prejudice, terrorism and behavior therapy. *Cognitive and Behavioral Practice, 9*, 296-301.

Heinrich, H. (1931). *Industrial accident prevention: A scientific approach*. New York, NY : McGraw Hill.

Huybers, S., Van Houten, R., & Malenfant, L. (2004). Reducing conflicts between motor vehicles and pedestrians: The separate and combined effects of pavement markings and a sign prompt. *Journal of Applied Behavior Analysis*, *37*, 445-456.

Johns Hopkins Injury Prevention Center (n.d.). *Injuries to bicyclists* (Monograph). Retrieved January 20, 2007, from http://helmets.org/stats.htm.

Krause, T. R., Hidley, J. H., & Hodson, S. J., (2001). *The behavior-based safety process: Managing involvement for an injury free culture* (2nd ed.). Van Nostrand Reinhold, New York.

Kulik, J. A., Kulik, C. L. C., & Cohen, P. A. (1979). A meta-analysis of outcome studies of Keller's Personalized System of Instruction. *American Psychologist, 34,* 307-318.

Lajunen, T., & Rasanen, M. (2004). Can social psychological models be used to promote bicycle helmet use among teenagers? A comparison of the Health Belief Model, Theory of Planned Behavior and the Locus of Control. *Journal of Safety Research*, *35*, 115-123.

Legg, S., Laurs, E., & Hedderley, D. (2003). How safe is bicycling with a schoolbag? *Economics*, *46*, 859-870.

Malott, R. (2002). What OBM needs is more Jewish mothers. *Journal of Organizational Behavior Management, 22*, 71-87.

McAfee, B., & Winn, A. (1989). The use of incentives/feedback to enhance work place safety: A critique of the literature. *Journal of Safety Research*, *20*, 7-19.

McSween, T. E. (2003). *The values-based safety process.* New Jersey: Wiley.

Michael, J. (1975). Positive and negative reinforcement: A distinction that is no longer necessary; or a better way to talk about bad things. *Behaviorism, 3*, 33-44.

Miller, J., Austin, J., & Rohn, D. (2004). Teaching pedestrian safety skills to children. *Environment and Behavior, 36*, 368-385.

National Highway Traffic Safety Administration. (2004). *Traffic safety facts* (DOT Publication No. 809 912). Washington, D.C.: Author. Retrieved on January 2, 2007, from http://www.nrd.nhtsa.dot.gov/pdf/nrd30/ncsa/TSF2004/809912.pdf.

Ortega, H., Shields, B., & Smith, G. (2004). Bicycle-related injuries to children and parental attitudes regarding bicycle safety. *Clinical Pediatrics*, *43*, 251-259.

Reschovsky, C. (2004). Journey to work, census 2000 brief. US Census Bureau, retrieved from: http://www.census.gov/prod/2004pubs/c2kbr-33.pdf.

Sidman, M. (2006). The distinction between positive and negative reinforcement: Some additional considerations. *The Behavior Analyst, 29*, 135-139.

Siggurdsson, S., & Austin, J. (2006). Institutionalization and response maintenance in organizational behavior management. *Journal of Organizational Behavior Management, 26*, 41-77.

Skinner, B. F. (1948). *Walden two.* Oxford, England: Macmillian.

Skinner, B. F. (1950). Are theories of learning necessary? *Psychological Review, 57*, 193-216.

Staats, A. W., & Staats, C. K. (1958). Attitudes established by classical conditioning. *Journal of Abnormal and Social Psychology, 57*, 37-40.

Streff, F. M. & Geller, E. S. (1988). An experimental test of risk compensation: Between-subject versus within-subject analysis. *Accident Analysis and Prevention, 20*, 277-287.

Sulzer-Azaroff, B. (1978). Behavioral ecology and incident prevention. *Journal of Organizational Behavior Management, 2,* 122-130.

Sulzer-Azaroff, B. & Austin, J. (2000). Does BBS work? Behavior-based safety & injury reduction: A survey of the evidence. *Professional Safety, 45*, 19-24.

Thompson, N., Sleet, D., & Sacks, J. (2002). Increasing the use of bicycle helmets: lessons from behavioral science. *Patient Education & Counseling*, *46*, 191-197.

US Department of Transportation, (1998). *Improving conditions for bicycling and walking: A best practices report*. US Department of Transportation, January.

Van Houten, R. (1988). The effects of advance stop lines and sign prompts on pedestrian safety in a crosswalk on a multilane highway. *Journal of Applied Behavior Analysis*, *21*, 245-251.

Van Houten, R., & Malenfant, L. (2004). Effects of a driver enforcement program on yielding to pedestrians. *Journal of Applied Behavior Analysis*, *37*, 351-363.

Van Houten, R., Malenfant, L., Zhao, N., Ko, B., & Van Houten, J. (2005). Evaluation of two methods of prompting drivers to use specific exits on conflicts between vehicles at the critical exit. *Journal of Applied Behavior Analysis*, *38*, 289-301.

Van Houten, R., & Retting, R. (2001). Increasing motorist compliance and caution at stop signs. *Journal of Applied Behavior Analysis*, *34*, 185-193.

Walker, I. (2007). Drivers overtaking bicyclists: Objective data on the effects of riding position, helmet use, vehicle type and apparent gender. *Accident Analysis and Prevention, 39*, 417-425.

Wiebe, M. (2006). US imports up; mass market looks to cash in on road. *Bicycle Retailer & Industry News*, April.

Wilde, G. (1994). *Target risk: Dealing with the danger of death, disease, and damage in everyday decisions*. Toronto, Ontario, Canada: PDE Publications.