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Mapping the Complex Causal Mechanisms of Drinking and Driving Behaviors Among Adolescents and Young Adults

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Abstract

Background.—The proportion of motor vehicle crash fatalities involving alcohol-impaired drivers declined substantially between 1982 and 1997, but progress stopped after 1997. The systemic complexity of alcohol-impaired driving contributes to the persistence of this problem. This study aims to identify and map key feedback mechanisms that affect alcohol-impaired driving among adolescents and young adults in the U.S.

Methods.—We apply the system dynamics approach to the problem of alcohol-impaired driving and bring a feedback perspective for understanding drivers and inhibitors of the problem. The causal loop diagram (i.e., map of dynamic hypotheses about the structure of the system producing observed behaviors over time) developed in this study is based on the output of two group model building sessions conducted with multidisciplinary subject-matter experts bolstered with extensive literature review.

Results.—The causal loop diagram depicts diverse influences on youth impaired driving including parents, peers, policies, law enforcement, and the alcohol industry. Embedded in these feedback loops are the physical flow of youth between the categories of abstainers, drinkers who do not drive after drinking, and drinkers who drive after drinking. We identify key inertial factors, discuss how delay and feedback processes affect observed behaviors over time, and suggest strategies to reduce youth impaired driving.

Conclusion.—This review presents the first causal loop diagram of alcohol-impaired driving among adolescents and it is a vital first step toward quantitative simulation modeling of the problem. Through continued research, this model could provide a powerful tool for understanding the systemic complexity of impaired driving among adolescents, and identifying effective prevention practices and policies to reduce youth impaired driving.

Keywords

Youth drinking and driving; System dynamics; Peers; Parental monitoring; Health policies; Alcohol

Introduction

In 2018, 1,719 drivers aged 15 to 20 were killed in motor vehicle crashes in the U.S.; twenty-four percent in alcohol-related crashes (National Center for Statistics and Analysis, 2020, October). Driving while impaired (DWI) is prevalent among adolescents and young adults. In a nationally representative study, 13% of 11th-grade students reported alcohol-related DWI in the past 30 days (Li et al., 2013). Complex, multi-level factors including binge drinking, peer influences, parental monitoring, alcohol marketing, governmental regulations, and enforcement strategies contribute to DWI among adolescents and young drivers.

Multiple risk factors of DWI have been identified by past research. Binge drinking is significantly associated with impaired driving (Terry-McElrath et al., 2014, Vaca et al., 2020). The prevalence of binge drinking increases during high school and by 12th grade, 27% of students binge drink (Vaca et al., 2020). Perception of peer binge drinking, which

is often higher than actual peer binge drinking, is a strong predictor of adolescents and young adults binge drinking (Robinson et al., 2015). Peers affect adolescents' binge drinking behavior through social modeling and perceived norms (Borsari and Carey, 2001, Patrick et al., 2013).

Perception of peer alcohol use is a strong predictor of initiation and consumption of alcohol. The perception of peer alcohol use is created through different mechanisms including exposure to alcohol-related content on social media (Curtis et al., 2018) and drinking with peers (Brooks-Russell et al., 2014). Adolescents with more friends who post partying/drinking pictures on social media are more likely to use alcohol (Huang et al., 2014), and exposure to alcohol-related content on social networking sites predicts onset of drinking and heavy drinking a year later (Nesi et al., 2017). In addition, drinking with peers is positively associated with perceived peer alcohol use, which, in turn, predicts alcohol consumption for both female and male adolescents (Brooks-Russell et al., 2014).

Multiple systematic literature reviews have found alcohol marketing significantly impacts alcohol consumption and drinking initiation among adolescents and young adults (Boggs, 2017, Gupta et al., 2016, Jernigan et al., 2017, Smith and Foxcroft, 2009, Stautz et al., 2016). Each additional dollar per capita spent on alcohol marketing is associated with 3% increase in alcohol consumption by individuals aged 15 to 26 (Snyder et al., 2006). In addition, each additional hour of exposure watching alcohol use in movies is associated with 15% increase in the probability of initiating alcohol use in the next year (Sargent et al., 2006).

Factors that protect adolescents from engaging in alcohol use and DWI such as parental monitoring, laws, regulations, and enforcement have been examined extensively. Parenting can be pivotal in limiting drinking and driving. Parents setting expectations for not-drinking and being more involved in their adolescent's life reduces adolescent drinking progression directly and indirectly by reducing the number of friends who drink (Simons-Morton and Chen, 2005). A systematic review of longitudinal studies showed that multiple parental strategies predict lower consumption of alcohol and delayed alcohol initiation (Ryan et al., 2010). Factors that reduce parental drinking should also reduce the likelihood of DWI. How much parents know about their adolescents' lives, such as how and with whom they spend their time, is another protective factor against DWI (Li et al., 2014, Li et al., 2015, Vaca et al., 2021, Vaca et al., 2020).

Between 1982 and 1997, the percent of drivers aged 21 to 24 in fatal crashes declined (Figure 1, Panel A, dashed line). The same trend is observed for those aged 16 to 20 (Panel A, solid line). Several state and federal impaired-driving laws enacted since 1980 may have contributed to the reduction (Fell et al., 2016). Founded in 1980, Mothers against Drunk Driving (MADD) contributed to changing the public's view on drunk driving and encouraged legislators to enact laws (Fell and Voas, 2006). By 1988, all states raised their minimum legal drinking age (MLDA) to 21. Between 1990 and 1998, all states adopted zero-tolerance laws that made it illegal for underage drivers to have any level of alcohol in their bodies (Hedlund et al., 2001). By 1997, 40 states passed the Administrative License Revocation (ALR) laws, which allowed for the immediate revocation or suspension of a

driving license for an individual who fails a BAC test or refuses to take the test (Dang, 2008).

Enforcement of these laws is not uniform across all states. However, highly publicized and visible enforcement deters drinking and driving as evidenced by a decline in the probability of drinking and driving as the population-based rate of police traffic stops increases (Fell et al., 2015) and the association between a 10% increase in arrest rate of impaired driving with a 1% reduction in DWI crash rate (Fell et al., 2014). Between 1995 and 2008, the number of young adults arrested for DWI increased, and declined thereafter (Figure 1, Panel B, dashed line). DWI arrests for individuals 16 to 20 followed a similar trend (Figure 1, Panel B).

Past studies identified different determinants of DWI among adolescents and young adults. However, they have not examined the interactions of these factors. Many public health problems persist because the complexity and interactivity inherent in these problems cannot be addressed by “single-cause” and “single-discipline” models (Livingood et al., 2011, Mabry et al., 2008). Systems science complements common approaches by considering interactions among factors, time delays inherent in systems, and unintended consequences of interventions (Mabry et al., 2008).

Adolescents’ drinking and driving behavior is a complex health problem affected by multi-level factors that often interact. Applying an appropriate method that can capture complex interactions among different factors and elicit relevant information from a wide range of disciplines can provide new insights about DWI among adolescents and improve prevention policies. System dynamics (SD) is an approach for understanding the structure and analyzing the dynamics of complex systems (Sterman, 2000, Forrester, 1961, Richardson, 1999). Dynamic complexities arise from interactions between elements of a system (i.e., feedback loops) and accumulations (i.e., stocks) of people, materials, or even information. The SD approach has been applied to a variety of health problems including diabetes, cardiovascular diseases, major depressive disorder, polio, and HIV (Darabi and Hosseinichimeh, 2020) to model the causal structure underlying the problem and conduct “what-if” analysis.

Accordingly, the objective of this study was to identify and map key factors, their interactions, and feedback mechanisms that affect alcohol-related DWI among adolescents and young adults in the U.S. These mechanisms were hypothesized by multidisciplinary subject-matter experts in two group model building (GMB) sessions, bolstered with a comprehensive literature review. The trends of key factors are explained by the causal loop diagram (CLD) developed in this study and insights are discussed.

Methods

We conducted two group model building (GMB) sessions with a multi-disciplinary group of subject matter experts to identify and map key mechanisms and feedback processes affecting DWI. Group model building (GMB) is a participatory form of developing an SD model (Andersen and Richardson, 1997, Andersen et al., 2007, Hosseinichimeh et al., 2017). A GMB session consists of structured activities guided by “scripts” for facilitators to elicit

knowledge from subject matter experts and hypothesize reciprocal processes of complex systems (Hosseinichimeh et al., 2019, Ivana et al., 2021, McGill et al., 2021).

Participants in the two GMB sessions consisted of high-level content experts in the medical, epidemiology, public health, policy, traffic safety, adolescent development, youth behavior, and health statistics fields. The first GMB session was conducted in-person in October 2019 and multiple scripts were used to extract key variables and potential policies, and to conceptualize the feedback processes underlying DWI. Between the two GMB sessions, a causal loop diagram (CLD) and a formal simulation model were built based on the hypothesized mechanisms in the first GMB session. In the second GMB session, which was conducted virtually in November 2020, the same participants simulated the SD model, provided feedback and improved the CLD. The CLD presented in this article reflects the modification that we made after the second GMB session. A CLD presents the reciprocal relationships among variables in a SD model and includes balancing and reinforcing feedback loops (Burrell et al., 2021). A feedback loop is a series of variables and causal links that create a closed loop of causal influences. Reinforcing feedback loops tend to reinforce the direction of original change of any variable in the loop. For instance, as people spend more money on alcohol, the revenue of the alcohol industry increases, leading to higher spending on alcohol advertisements. More alcohol advertising leads to more people exposed to advertising and then more initiating alcohol drinking and, in turn, increased alcohol consumption and increased revenues for advertising. Balancing feedback loops push back in the opposite direction of the original change in a variable in the loop. For example, as the number of young impaired drivers increase, the number of DWI trips rise, which leads to a higher number of DWI trips caught by parents. A higher number of DWI trips caught by parents increases parental monitoring, which reduces the number of young impaired drivers. The initial increase in impaired drivers works around the balancing feedback loop to reduce the number of impaired drivers.

We also conducted a comprehensive literature review to identify potential mechanisms through which risk factors—peers, binge drinking, alcohol marketing—and protective factors—parental monitoring, laws, regulations, and enforcement—influence DWI. Web of Science and MEDLINE databases were searched to identify recent articles—published between 2000 and 2021. The search terms that we used to identify related articles are listed in the appendix. We only included articles published in English. References of these articles were checked to find more relevant papers. In addition, we used three GMB scripts to elicit references from subject-matter experts and identify key publications related to each factor. The study protocol was approved by the Institutional Review Board of Yale University.

Results

Participants categorized adolescents and young adults in multiple stocks including *Abstainers*, *Drinkers who do not drive after drinking*, *Drinkers who drive after drinking*, and *Never DWI again*. *Abstainers* do not drink, *Drinkers who do not drive after drinking* are individuals who drink but do not drive under alcohol influence, *Drinkers who drive after drinking* are adolescents who drink and drive, and *Never DWI again* are individuals who are arrested due to impaired driving and they stopped drunk driving after the arrest (Figure 2).

The number of adolescents in each category (i.e., stock) changes by the inflows and outflows of these stocks. For instance, the number of *Abstainers* increases by its inflow—*Drinkers becoming abstainers*—and declines by its outflow—*Abstainers becoming drinkers* (Figure 2). The flows that determine the number of individuals in each category are regulated by multiple mechanisms presented in the next figures.

The flow, *Abstainers becoming drinkers*, is affected by *Perceived peer drinking* and *alcohol advertisement* (Figure 3). Alcohol advertisements have a significant influence on initiation and amount of consumption of alcohol among adolescents (Boggs, 2017, Gupta et al., 2016, Smith and Foxcroft, 2009, Stautz et al., 2016). Advertising is part of a loop involving alcohol consumption and revenue. *Spending on alcohol* is determined by *Total drinkers* and *Alcohol consumption* per capita. More *Spending on alcohol* increases *Alcohol industry revenue* per year. Usually, the alcohol industry spends 9% of its revenue on marketing (Federal Trade Commission, 2014), which elevates *Alcohol consumption* per capita (Snyder et al., 2006) in the absence of other counteracting mechanism (reinforcing loop R1, Marketing Influence on Consumption) and leads to higher *Spending on alcohol*. In addition, higher revenue and marketing increase the risk of starting to drink (Sargent et al., 2006) and adds to the population of drinkers (reinforcing loop R2, Marketing Influence on Drinking Initiation).

Peer drinking is a strong predictor of adolescents drinking initiation and consumption (Curtis et al., 2018, Huang et al., 2014, Nesi et al., 2017, Simons-Morton et al., 2018). Individuals often overestimate their peers' drinking frequency and quantity, which affect their own drinking (Giese et al., 2019). As the number of drinkers in a community increases, *Estimated peer drinking* goes up, which increases the *Perceived peer drinking* and leads to more *Abstainers becoming drinkers* (reinforcing loop R3, Peer Influences on Drinking Initiation) and higher *Alcohol consumption* (reinforcing loop R4, Peer Influences on Alcohol Consumption).

Average *Alcohol consumption* level (i.e., number of drinks per person per a period of time) and *Perceived peer drinking* are two key stock variables that change slowly, likely in the order of years. Dynamics of *Perceived peer drinking* affect the movement of individuals from the *Abstainer* group to the *Drinkers who do not drive after drinking* category. It might change quickly when R1 acts as a vicious cycle, and slowly when the loop acts as a virtuous cycle.

Peer influence also affects adolescents' binge drinking behavior through social modeling and perceived norms (Borsari and Carey, 2001, Patrick et al., 2013). As more adolescents engage in binge drinking, *perceived peer binge drinking* increases which leads to a higher *Fraction of drinkers who binge but do not drive after drinking* (reinforcing loop R5 in Figure 4) and *Fraction of drinkers who binge and drive after drinking* (reinforcing loop R6). Binge drinking is positively associated with DWI (Vaca et al., 2020). As a result, more binge drinking leads to a higher number of *Drinkers becoming alcohol-impaired drivers* and increases *Average frequency of DWI* (Figure 4).

The key stock variable is *Perceived peer binge drinking*, which affects the behavior of both the *Average frequency of DWI* and the number of *Drinkers becoming Alcohol-impaired drivers*. Similar to the perceived peer drinking, it might change quickly when the related reinforcing loops work as vicious cycles, and slowly when the loops act as a virtuous cycle.

As illustrated in Figure 5, the number of *DWI trips* is a product of “*Average frequency of DWT*” and the number of “*Drinkers who drive after drinking*.” With all other conditions held constant, an increase in the number of *DWI trips* will increase both *Crash-* and *Non-crash-DWI trips*. This increase, in turn, will raise the number of arrests for DWI thus reducing the number of *Drinkers who drive after drinking* (balancing loop B1, Enforcement). Some drivers who experience *Non-crash DWI trips* may stop impaired driving (balancing loop B2, Near Crashes). In addition, more arrests enhance *Visibility of enforcement* and increase the perception that drunk drivers get caught, which increases the number of *Alcohol-impaired drivers stopping DWI* and reduces the number of *Drinkers becoming Alcohol-impaired drivers* (balancing loop B3, Perception of Enforcement).

As the number of *Fatal DWI trips* increases, *Pressure on lawmakers* rises and they enact *DWI restrictive policies* that may reduce the number of *Drinkers becoming Alcohol-impaired drivers* and increase the number of *Alcohol-impaired drivers stopping DWI* (balancing loop B4, DWI Policy Influences on Drinkers Who Drive after Drinking). In addition, these regulations might affect the “*Average frequency of DWT*” and reduce “*DWI trips*” (balancing loop B5, DWI Policy Influences on DWI Frequency). Finally, some *DWI trips* would be caught by parents, which may increase parental supervision and increase the number of *Alcohol-impaired drivers stopping DWI*, and reduce the number of *Drinkers becoming Alcohol-impaired drivers* (balancing loop B6, Parental Influence).

The key stocks are *Perception will get caught*, *DWI restrictive policies*, *Average frequency of DWI*, and *Pressure on lawmakers*. Speed of change in *Perception will get caught* is probably on the order of months or years. It takes years to build *Pressure on lawmakers* and enact new *DWI restrictive policies*.

A variety of interventions have targeted alcohol-impaired driving among young people in the U.S. Here we provide a couple of examples to demonstrate where on the causal loop diagram they can be captured. Restrictive alcohol policies are associated with fewer alcohol-related motor vehicle crash fatalities (Hadland et al., 2017). Examples of a strong restrictive alcohol environment include, having a functional and adequately staffed alcohol beverage control agency, hours of sale restrictions, and house party laws, which reduce underage *Alcohol consumption* in the feedback loop R1 and R2. *DWI restrictive policies* such as 0.08 per se law and minimum legal drinking age also reduce *Alcohol consumption* (the link is not shown in Figure 5). In addition, correcting *Bias toward peer drinking* through social norms campaigns in a college residence hall (Brooks-Russell et al., 2014) and individual-level interventions that enhance student’s confidence in resisting peer influence (Carey et al., 2004) can reduce *Alcohol consumption* (reinforcing loop R3 and R4). Similarly correcting *Bias toward binge drinking* reduces binge drinking (DiGuseppi et al., 2018) (reinforcing loop R5 and R6).

Interventions that enhance the *Visibility of enforcement* such as increasing the number of traffic stops and *DWI arrests* per capita are associated with lower probability of alcohol-impaired driving (Feedback loop B3) (Fell et al. 2015). Enacting more restrictive laws or enforcing the current laws more effectively can enhance the strength of feedback loops B4 and B5. Informing parents about the impact of parental practices on alcohol-impaired driving and binge drinking is another strategy to reduce fatalities related to alcohol-related motor vehicle crashes (Feedback loop B6).

Discussion

This study hypothesizes and maps causal feedback mechanisms influencing alcohol-impaired driving among adolescents and young adults in the U.S. through two GMB sessions with subject-matter experts and extensive review of the literature. The stock-flow structure and feedback loops presented in Figures 2–5 capture the key processes that affect the flow of adolescents and young adults in four categories: Abstainers, Drinkers who do not drive after drinking, Drinkers who drive after drinking, Never DWI again. The CLD provides insights about the structure creating the decline in drinking and driving between 1982 and 1997 and sheds light on where future policies should be aimed.

Figure 1.a. depicts the trend of percent of drivers in fatal crashes with $BAC > 0.08$. The CLD provides insights about the feedback mechanisms underlying the trend. The balancing loops B1 to B5 capture the mechanisms contributing to the reduction in the percent of drivers in fatal crashes between 1982 to 1997 (Figure 1, panel A.). As is shown in Figure 1 (Panel A), by 1998, all states passed multiple DWI laws that effectively reduced DWI fatalities. Enactment of these laws was not possible without advocacy groups (e.g., MADD) that turned statistics of DWI fatalities into personal stories of DWI victims and increased pressure on policymakers to take actions (balancing loop B5 and B6 in Figure 5). Since 1997, the trend of alcohol-related fatal crashes has not changed, which indicates that the system has settled down into a new steady state. This steady state is a result of one or more of the balancing loops (B1 to B5) dominating the system in recent years.

As shown in Figure 1 (Panel B), arrests increased from 1995 to 2008, and declined afterward while percent in fatal crashes has been stable. Two hypotheses might explain the observed behavior. First, the enforcement loops (B1 and B3) are weaker than the other loops and decline in arrests has not changed the DWI fatalities. Second, the speed of change in “*Perception will get caught*” by police is slow and drivers’ perception has not changed dramatically after the decline in arrests. Quantifying these feedback processes will allow for testing these hypotheses.

When acting as vicious cycles, the reinforcing loops R1 to R6 increase the flow of adolescents and young adults from the stock of *Abstainers* to the stocks of *Drinkers who do not drive after drinking* and *Drinkers who drive after drinking*. However, these reinforcing processes can be turned into virtuous cycles. For instance, as fewer adolescents engage in binge drinking, perceived peer binge drinking decreases, which leads to a lower *Fraction of drinkers who binge but do not drive after drinking* (reinforcing loop R5 in Figure 4 as a virtuous cycle). Stock variables in each loop and their speed of change are important

determinants of the strength of a reinforcing loop. Identifying factors affecting these stock variables and their speed of change is an important step toward better understanding of the DWI dynamic and can inform prevention policies.

The CLD also provides insights about the dynamic of youth drinking and driving behavior by identifying key inertial factors (stock variables) embedded in the reinforcing and balancing feedback loops. *Perceived peer drinking* and *binge drinking*, as well as, *Perception will be caught by police*, *Pressure on lawmakers*, and *DWI polices* are key stocks because their speed of change affects the dynamic of alcohol-impaired driving. It is possible that some of these stock variables, such as *Perceived peer binge drinking*, change quickly when the reinforcing loop acts as a vicious cycle and slowly when acting as a virtuous cycle. Future research is warranted to determine if such asymmetry exists in the dynamic of the key inertial factors.

Two main strategies can be followed to further reduce the incidence of drinking and driving among youth. First, interventions that focus on reducing the strength of the reinforcing loops when they act as vicious cycles or those that have the potential to turn them into virtuous cycles should be examined and emphasized. To reduce the strength of the reinforcing loops, the amount of spending by the alcohol industry on the marketing of alcohol should be reduced and the misperception about peer drinking behaviors should be corrected. Past studies showed that reducing misperception can lower reported DWI (Linkenbach and Perkins, 2005). Informing youth about the negative effects of initiating alcohol consumption at early age and promoting youth to encourage positive behaviors can turn the vicious cycles to virtuous cycles.

Second, the strength of the balancing processes should be increased. Balancing loops create goal seeking behaviors. To strengthen the balancing loops, we need to set higher goals at all levels (i.e., peer, family, enforcement, and legislation: Enhance existing enforcement of known effective drinking and driving laws already on the books, as well as programs aimed at getting parents more involved in monitoring youth drinking and driving. These two types of strategies eventually reduce or delay the flows of adolescents in the upstream stock (i.e., *Abstainers*) to downstream stocks (i.e., *Drinkers who do not drive after drinking*, and *Drinkers who drive after drinking*) or increase the upward flows.

Our next step will be to formulate the feedback processes discussed in this article and estimate model parameters through calibration using multiple sources of the data. After building confidence in the model, we plan to simulate the model and use the model to ask “what-if” questions to identify interventions and prevention activities and policies that can reduce DWI.

Limitations

While this qualitative study has been robust in process, nonetheless, this work likely has been affected by investigators’ and GMB participants’ biases. However, qualitative systems mapping of the drivers and inhibitors of DWI is the first step towards quantitative modeling of DWI, which will be used to examine and recommend prevention policies aimed at

reducing drinking and driving among adolescents. In addition, although the GMB exercise may have been influenced by individual biases, we tried to minimize such biases by inclusion of multiple diverse content experts, systematic elicitation of discordant views, facilitated group discussions to negotiate consensus where feasible, and a comprehensive literature review. Another limitation is that our causal loop diagram was informed by the existing literature. Some of the mechanisms are not yet well understood with a considerable paucity of published literature. As a result, the relative importance of these mechanisms is not known due to lack of published and accessible related data. While the relative importance of the mechanisms cannot be assessed within the constraints of the current study, we set out to generate hypotheses for future investigation and testing.

Conclusion

Drinking and driving among adolescents and young adults is a complex problem that involves a multitude of factors interacting over time. We have applied a system dynamics approach and mapped feedback mechanisms that affect alcohol-impaired driving to shed light on the structure that creates the trends of impaired driving over time and potential effective interventions to reduce it.

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Appendix:

Search terms used to identify articles for factors under consideration

Factor	Search terms	# of identified articles	# of abstracts reviewed	# of final articles reviewed
Binge drinking and impaired driving	TS=(binge drinking* AND impaired driving* AND adolescent)	42	23	13
Peer influence and drinking	TI=(Alcohol* AND peer* AND adolescent)	130	53	19
Alcohol advertisement	TS=(Alcohol* AND marketing* AND adolescent)	234	112	35
Parent and impaired driving	TS=(Parent* AND impaired driving* AND adolescent)	39	12	5
Enforcement and impaired driving	TS=(Enforcement* AND impaired driving* AND adolescent)	57	32	23

Factor	Search terms	# of identified articles	# of abstracts reviewed	# of final articles reviewed
Regulation and impaired driving	TS=(Regulation* AND impaired driving* AND adolescent)	36	9	5
Law and impaired driving	TS=(Law* AND impaired driving* AND adolescent)	105	43	12

Abbreviations:

GMB	group model building
SD	system dynamics
DWI	driving while impaired
MADD	mother against drunk driving
MLDA	minimum legal drinking age
BAC	blood alcohol concentration
ALR	administrative license revocation
CLD	causal loop diagram

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Highlights

- Fatalities related to alcohol-impaired driving in the U.S. have not changed since 1997.
- Major risk factors include binge drinking, peer influences, and alcohol marketing.
- Parental monitoring, regulations, and enforcement are protecting factors.
- We present the first map of feedback mechanisms regulating alcohol-impaired driving.

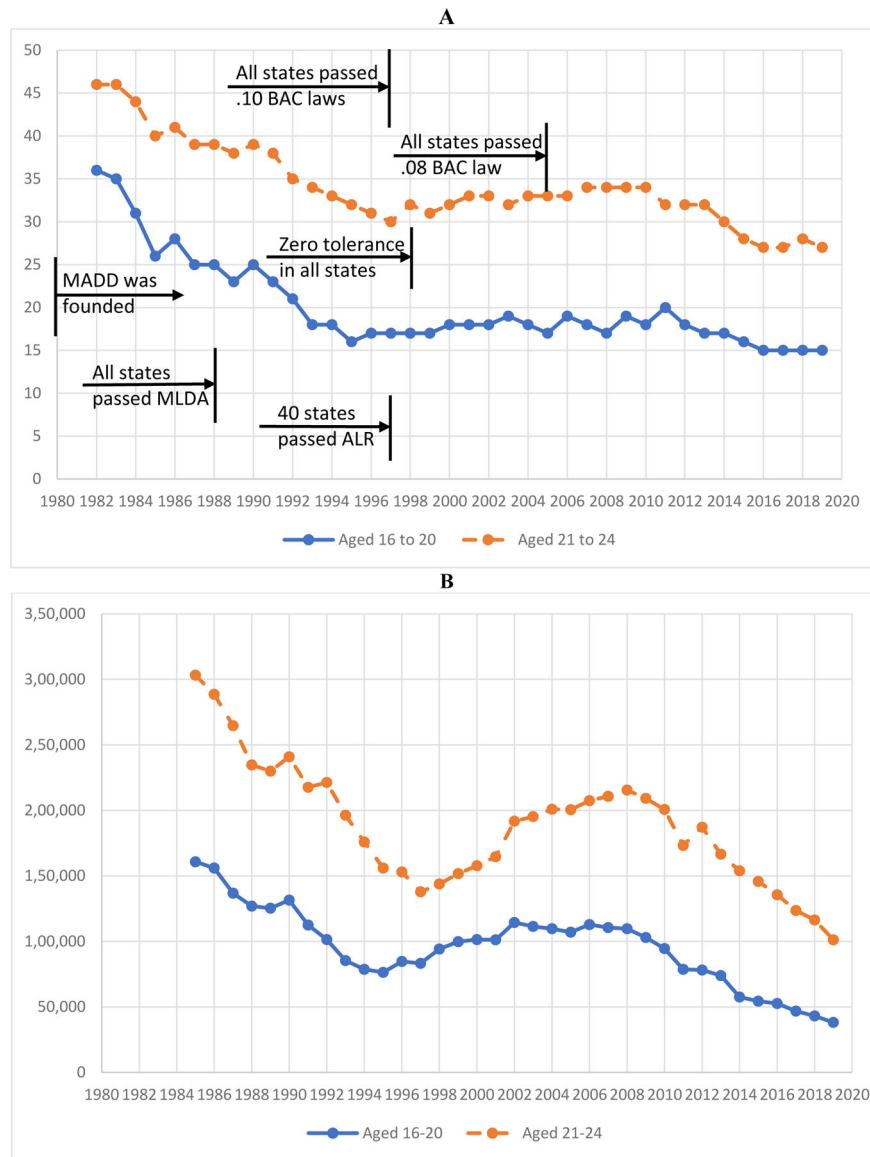


Fig. 1. (A) Percentage of drivers in fatal crashes with BAC $\geq .08+$ by age group and (B) percentage of drivers in fatal crashes with BAC = .08+ by age group. Sources: (A) FARS 1982–2018 Final, 2019 ARF; and (B) FBI website.

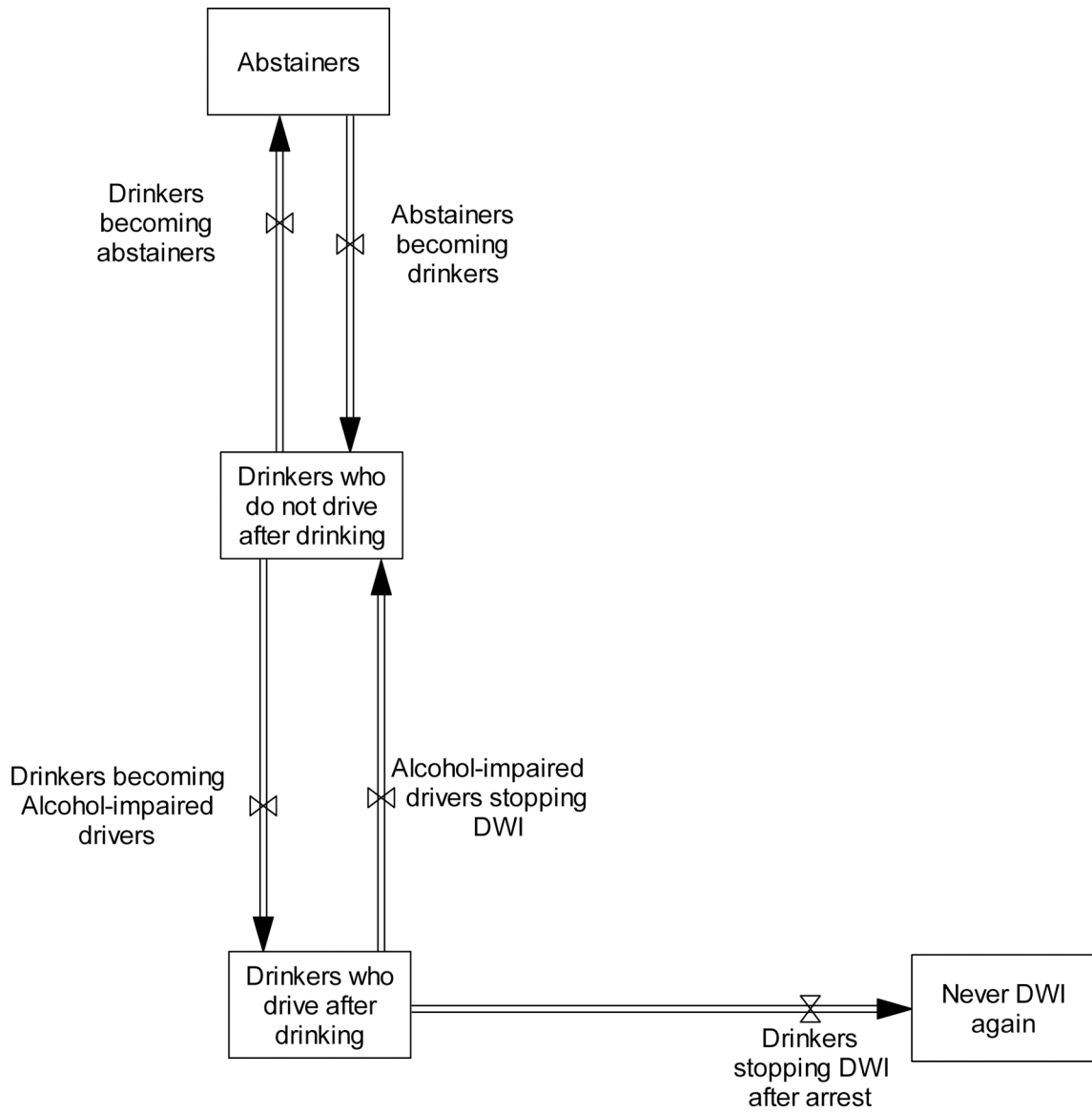


Fig. 2. Stock-flow diagram of Abstainers, Drinkers who do not drive after drinking, Drinkers who drive after drinking, and Never DWI again.

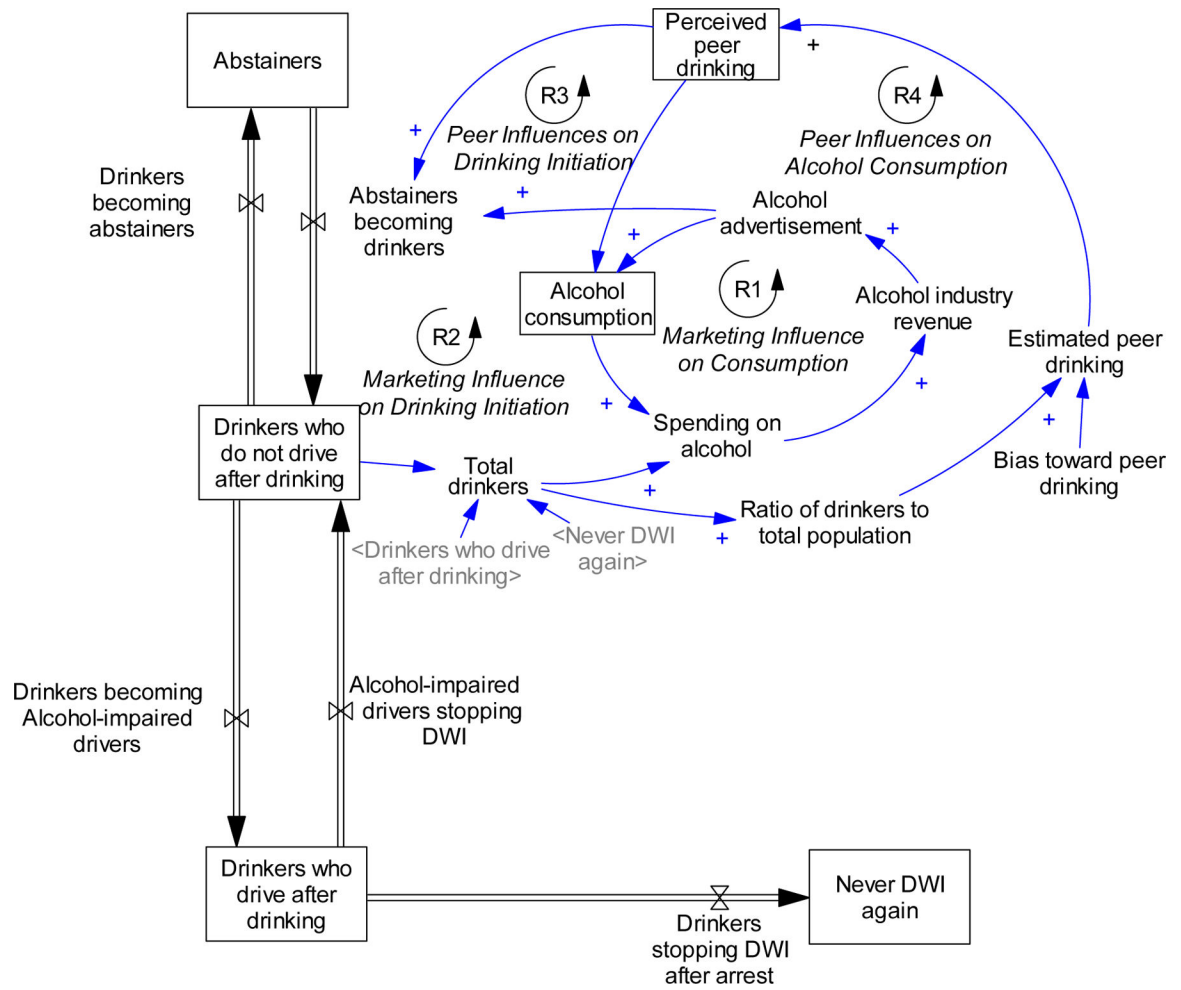


Fig. 3. Impact of marketing and peer influences on alcohol consumption and drinking initiation.

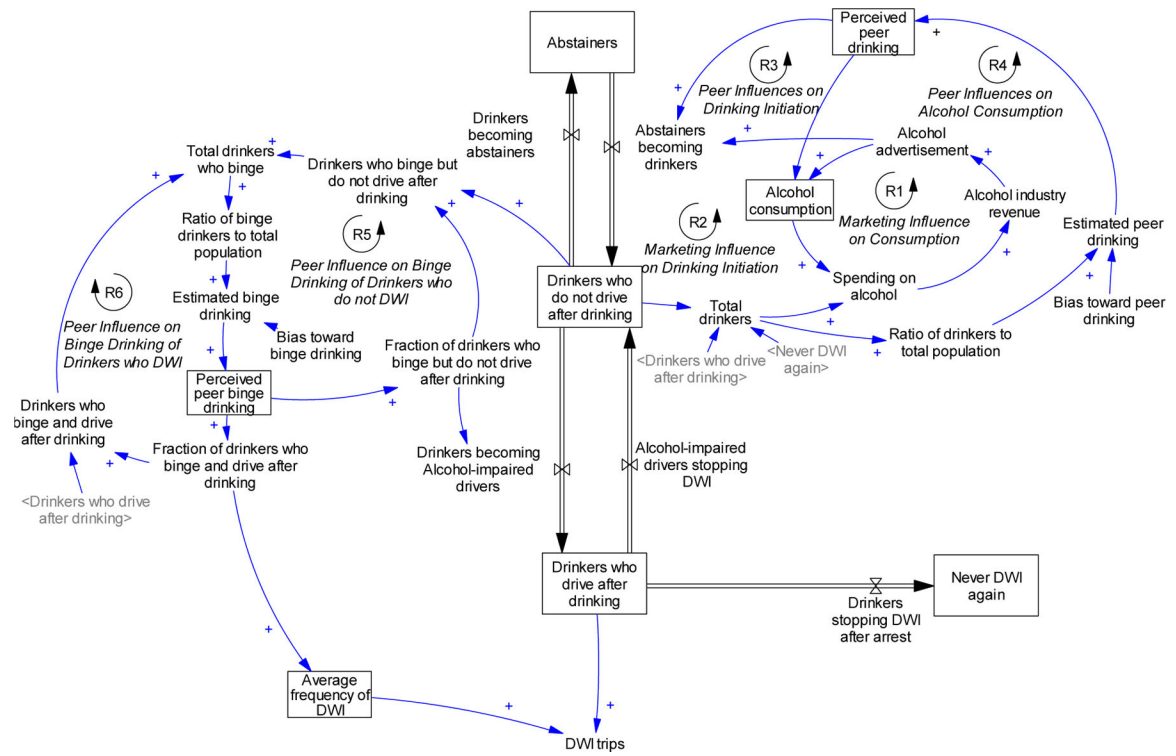


Fig. 4. Peer influences on binge drinking of drinkers.

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