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Abstract

This paper is based on my Research Laureate Address to the American Academy of Health Behavior, Portland Oregon, March 4th, 2018. The paper follows the basic content and structure of my address but has been written in a style more consistent with a scientific essay rather than a transcript of a verbatim speech.

Keywords

Drinking, Laureate Address, AAHB Annual Meeting

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The work discussed in this paper has been a long collaboration of numerous investigators including: Danielle Madden, Julie Croff, Mark Reed, Audrey Shillington, James Lange, Bob Voas, Brandy Martell, Hugo Gonzalez Villasanti, Luis Felipe Giraldo, Kevin Passino, Doug Mooney, Jong Won Min, Megan Holmes, and Lance Segars. This work could not have happened without their conceptual and methodological contributions or hard work in the field. Portions of this work were funded by the National Institute of Alcoholism and Alcohol Abuse, The Ohio State University, and The Conrad Hilton Foundation.

The Promise of Systems Science in Health Behavior Research: The Example of Studying Drinking Events

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This paper is based on my Research Laureate Address to the American Academy of Health Behavior, Portland Oregon, March 4th, 2018. The paper follows the basic content and structure of my address but has been written in a style more consistent with a scientific essay rather than a transcript of a verbatim speech. Some of the points made in the original talk have been elaborated, while various asides have been omitted. My hope is that this paper will serve as both a historical document of the 2018 Laureate Address and a source of future debate and discussion.

Conferences are interesting. In my experience, these meetings seem to serve three purposes: 1) they are a great place to network, 2) at times they are a source of true inspiration, and 3) they are often social events. This paper had its genesis at a series of AAHB annual meetings. Over the past several years, invited speakers at the AAHB annual meeting have stressed the complexity of health problems, the promise of "smart" interventions, the need to actively engage communities as partners, and the difficulty of implementing science-based interventions. Numerous such talks, coupled with discussions about them with colleagues over dinner (and, yes, drinks), influenced the work discussed below. Simply put, these meetings and annual interactions with talented colleagues spawned the ideas presented here and the gumption to actually act on them.

Specifically, four related ideas central to this paper were the foci of earlier AAHB meetings and have greatly influenced my current work:

1) Most health problems are complex and dynamic.
2) Transdisciplinary approaches that include non-traditional partners will be required to fully understand and solve health behavior problems.
3) Rapidly developing technology offers both an opportunity and a challenge for health behavior research and practice.
4) The engagement of community partners in the understanding of health behaviors and solutions to related problems is critical.

These ideas guided much of my work over the past few years. Given most of this work is published elsewhere, I will provide references for the interested reader and refrain from detailed discussions of the findings specific to my recent work. Rather, I hope to illustrate the main thesis of this paper—that systems science has great promise for health behavior research and practice—with a brief case study of my own pathway into doing systems science related to drinking behavior. Before presenting that brief case study, a bit of historical background might be of use to readers unfamiliar with systems or ecological approaches.

Systems Thinking in Health Behavior Research and Practice

Born of both the natural and social sciences, key systems concepts related to the conceptualization of behavior began to emerge in the 1950s (Boulding, 1956; von Bertalanffy, 1950). System models typically include domains (or parts), at multiple levels of abstraction, which are interconnected and influence each other over time (Meadows, 2008). Although systems can be strictly linear, complex systems tend to have feedback loops that result in bidirectional causation and non-linear outcomes (see Clapp et al, 2018). One feature of complex systems of particular interest for health behavior intervention research is the notion of "leverage points," which represent strategic places in complex systems where an intervention will likely lead to a large change in the behavior of the system (Meadows, 1999; Stokols, 2000).

Since the 1980s health behavior research and education has embraced a systems or ecological approach. Indeed, "ecological frameworks" (Boleyn & Honari, 1999), "cell to society models" (Hovell, Walhgren, & Adams, 2009), and the like can be found in public health (Hovell et al., 2009), social work (Payne, 2014), community psychology (Kelly, 1966), social ecology (Stokols, 2000), human development (Bronfenbrenner, 1979), and other fields that have heavily influenced health behavior research. Although such conceptualizations vary in complexity and specification, all share an almost universal (whether it be explicit or tacit) intent of guiding the understanding of the etiology of health problems and, by extension, research and practice (Green & Kreuter, 2000; Homer & Hirsh, 2006; Hovmand, 2014).

The most basic system model related to our work is arguably the hierarchical "public health model" of agent, host, and environment, which serves as a basic heuristic for public health research and practice. On the more complex side of the spectrum, for example, is Hovell's Behavioral Epidemiological Model (Hovell et al., 2009), which posits that cross-level reinforcing contingencies ranging from the cellular level to the cultural level drive health behavior. Such models are institutionalized in the curricula of health education (Green & Kreuter, 2000), public health (Mausner & Bahn, 1985) and social work (Greene, 1999), and often appear in the research literature as conceptual structures for organizing statistical models and explanatory study designs (Hovell, et al., 1994).

Systems approaches, with all their promise of the ability to explore complicated phenomena are, however, not without criticism. Wakefield (1996), for instance, suggested that systems and ecological approaches are mere metaphors for etiology and lack the specificity to truly be useful. Essentially, this common critique suggests that systems and ecological models fall short of specified traditional theories. Thus, traditionally trained quantitative health behavior scientists often view these models as being underspecified (i.e., too vague) or over-specified (i.e., "everything and the kitchen sink"). To be fair, these critiques are not without merit. Systems and ecological models can be underspecified, over-specified, and/or devoid of theory or grounding in the scientific literature. It can be argued, however, that these limitations are largely a function of a few important structural barriers that make doing systems science related to health behaviors a challenge.

Some Barriers to Advancing Systems Science

Despite our exposure to systems and ecological approaches in graduate school, we are not adequately trained to "think" about systems, let alone study or intervene in them (see Miller & Page, 2007; Riley et al., 2011). While as noted earlier, most social work, public health, and health behavior students and professionals are exposed to ecological models, they are seldom taught the modeling process, the concepts of positive and negative feedback, or how feedback loops impact behavior over time (Miller & Page, 2007). Similarly, most researchers in health behavior fields are taught traditional linear statistical methods and theories that seldom examine the bidirectional feedback relationships between domains at multi-levels of abstraction. Such training typically results in explanatory studies focusing on a single level of abstraction or

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hierarchical models (i.e., person-level and environmental-level). While traditional research trajectories often follow a finite linear path—Study A (pilot) leads to Study B (RTC), Study B leads to Study C (RCT with new population or replication)—the modeling process for complex problems often follows a non-linear and iterative course. In systems science, Study A (conceptual work) might lead to Study B (simulation), then Study C (field study), which in turn lead to a revisit of Study A (conceptual work) and Study D (new simulations). In some ways the model-building process is similar to a grounded theory approach (Glaser & Strauss, 1999), where observations (in this case both empirical and simulated) lead to better models and theory through a process of ongoing refinement. As such, the process of thinking about, tuning, and validating models suggests the entire modeling enterprise is at-best long term but arguably infinite.

Complex and dynamic problems are seldom solved in isolation with simply solutions. Conceptualization, model specification, simulation, and the like often require a team of scientists working on the problem. As researchers, we are often ill-prepared to engage in team science (Hall et al., 2012). Scientists of my generation where not trained in team science. Few current doctoral programs provide such training. In the end, many of the scientists working in transdisciplinary teams simply figured it out themselves. This is not a quick or easy process. Sitting down and explaining a health behavior theory and the related literature to engineers or computer scientists and simultaneously becoming conversant and conceptually adept in their methods and modeling approaches requires patience and humility on both sides; the mutual understanding of complex problems simply takes time.

Taken together, these gaps in our education are themselves a function of a complex system—where what gets taught influences what gets published, funded, and recognized in tenure decisions, which in turn reinforces curriculum. These structural barriers can make undertaking systems science less appealing and more daunting to senior faculty and downright prohibitive for junior faculty and doctoral students.

Despite barriers, numerous interesting trends in systems modeling, consistent with the needs of health behavior researchers and professionals, are emerging. Community-based system dynamics modeling (Hovmand, 2014) and collaborative or participatory modeling (Basco-Carerra, Warren, van Beek, Jonoski, & Giardino, 2017), for instance, involve community members impacted by a particular problem in the modeling of both the etiology of the problem and its potential solutions. These modeling exercises have been used by environmental resource managers (see Basco-Carerra et al., 2017), as well as social work and public health professionals (Hovmand, 2014), and to influence solutions to manmade disasters like the Flint, Michigan water crisis (Gray, Singer, Schmitt-Olabisi, Introne, & Henderson, 2017). These efforts are consistent with the spirit of community-based participatory research and result in a shared understanding that can help guide solutions.

In addition to collaborative modeling, computer software used for system dynamic modeling, agent-based modeling, and the like has become more accessible to social and health behavior scientists. Software like Vensim, STELLA, and NetLogo are all fairly easy to learn. STELLA provides online courses and excellent supporting materials and several aftermarket resources exist for Vensim and NetLogo. It is important to note that these software packages are nothe best tools for mathematical modeling and that engineers and computer scientists tend to use more advanced packages. That said, these tools are useful to create visualizations to communicate both within yourown team and with other health behavior researchers. These tools also offer a way to simulate the effects of potential interventions.

The Promise of Systems Science: The Case of Drinking Events

My journey into systems science is probably not unlike many social and health behavior scientists who are now working with engineers and computer scientists to better understand and hopefully reduce complex health problems. As a master's student, I completed a thesis that examined epidemiological trends in drinking and alcohol-related problems at the population level. In this research, I took the very basic epidemiological approach of correlating typical 30-day drinking patterns to typical alcohol-related problems (Clapp & Segars, 1993). Nonetheless, in the course of my studies, I came across two texts that resonated with the heuristic systems models I learned in social work. The first was an NIAAA (National Institute on Alcohol Abuse and Alcoholism) monograph entitled "Social Drinking Contexts" (Harford & Gaines, 1982), which included several interesting chapters discussing the difficulty of measuring and modeling drinking contexts. One particular passage stuck with me:

> "(the environment) persists in being a concept of disturbing *complexity*" (p. 230). And second, "the *dynamics* of situations give rise to changes in situations and behavior over time…an obvious source of such change is…alcohol ingestion…and its disinhibition effects" (p. 231; emphasis added) (Jessor, 1982).

Recognizing the inherent limitations of the simple epidemiological analysis utilized in my thesis, I began to develop an interest in how drinking occurred at the event-level. Acute alcohol problems, which occur at the event level, have a huge global impact (Rehm et al., 2009); for instance, approximately 25% of all unintentional, and 10% of intentional injuries in the world can be attributed to drinking events. In aggregate, drinking events represent patterns of consumption that drive disease and premature death (Holder, 2006).

Drinking events are inherently conducive to systems approaches as events commonly include the drinker, a social network, a social environment, and a built environment. Conceptually, it is not difficult to make the case that these various domains, representing different levels of abstraction, influence drinking behavior. Despite this, the barriers to doing systems science noted earlier were very real at the time, and my colleagues and I embarked on studies grounded in social science methods.

Much of my early work (Clapp, Shillington, & Segars, 2000; Clapp & Shillington, 2001; Clapp et al., 2003) examined behavior during the drinker's last drinking event (that occurred sometime during the past two weeks). My colleagues and I developed and used a comprehensive event follow-back measure that looked at several domains we believed influenced drinking behavior and related problems including time, place, motives, social purpose, and the like. These early studies used cross-sectional survey methods and standard multivariate (e.g., logistic regression, ordinary least squares multiple regression, and structural equation modeling) and multi-level models (e.g., hierarchical linear modeling). This common approach in model building results in elegant statistical models but often at the expense of understanding complexity underlying relationships among these modeled constructs in the real world.

Although survey methodology remains a staple of both health behavior and alcohol research, the method has numerous limitations when trying to understand drinking events. The underlying concern with these methods centers on respondents' inabilities to reliably recall their own drinking behaviors, motives, and environmental factors, as well as other momentary factors, cognitions, and behaviors. To address this concern, my colleagues and I developed a set of field

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methods to assess drinking in situ (Clapp et al., 2007). In the mid-2000s, we began a series of field studies we informally called the "Bar and Party" project. These studies examined drinking behavior in the field from an ecological perspective. Mixed-method in design, these studies (Clapp et al., 2007) relied on observation, field interviews, telephone surveys, and the collection of breath alcohol samples (BrAC) to better understand heavy drinking and related problems in context. While others had studied behavior in bars (starting with Sherri Cavan's 1960s ethnography of bars in San Francisco), our study was one of the first to explore party settings using a field methodology (Clapp, Min, Shillington, Reed, & Croff, 2008).

While these studies (Clapp et al., 2008; Clapp et al., 2009) were generally well received in the alcohol research community and garnered attention in popular media, conceptually I felt the data they yielded provided an incomplete picture of the complexity of drinking behavior at the event-level. The limitations were serious. The cross-sectional or very limited time-series (i.e., two points in time) nature of the data did not allow an assessment of dynamics within individuals, peer networks, or environments. By combining BrAC values and interview data, we were able to get a sense of the trajectory of the blood alcohol curves (BAC) of our participants, but only in the most rudimentary way. We were left with more questions than answers: Were BAC trajectories linear? How did a drinker's motives shift over the course of an event? How did individual motives, peer influence, and environmental factors vary with BAC? Most importantly, how did these domains influence each other dynamically? That is, how did the drinking event system influence drinking behavior *over time*?

Replicating these studies, even in an expanded way, would not address these questions. The issues were both methodological and conceptual. Methodologically, we needed to develop methods to capture the dynamics of an event and BAC. Although diary studies and ecological momentary assessments (EMA) were an option, responses still depended on self-report. Collecting repeated biological samples during an event with breathalyzers was not practical. At the time, global positioning systems (GPS) and smart phone technology were not amenable to field research, nor widely used. Conceptually, we developed or refined theories or collected empirical evidence at the various levels of abstraction in our model, but had no coherent way to knit those various streams of work together in a fashion that addressed dynamics between domains. For instance, we used principles from normative social psychological theory (Trim, Clapp, Reed, Shillington, & Thombs, 2011; Reed, Clapp, Martell, & Hidalgo-Sotelo, 2013; Villarosa, Madson, Zeigler-Hill, Noble, & Mohn, 2014; Weitzman, Nelson, & Wechsler, 2003) to examine how motives and peer influence conceptually operate to influence drinking. At the same time, we understood there are environmental influences on drinking including, for instance, price (O'Mara et al., 2009), music (Hughes et al., 2012), and the availability of food (Carlini et al., 2014), which can influence drinking behavior. Although we learned much about how relationships between constructs might operate within domains, we had no clear way to determine how these constructs might operate in dynamic models.

As is often the case in science, our experiences were mirrored by others working on similar complex problems. These collective experiences likely helped fuel the developments in systems science, team science, and accessible modeling software mentioned earlier. Still, finding a willing partner in engineering or computer science and then doing the work is another matter. In 2013, I was fortunate enough to meet Kevin Passino, an engineering professor at The Ohio State University with an interest in modeling complex systems. Professor Passino had spent about a decade modeling bee behavior related to swarm dynamics and locating new hive locations (Passino & Seeley, 2006). He explained that the modeling process would be an intensive and joint effort that would require time. Our collaboration in developing system dynamics models of drinking events has been described elsewhere (Clapp et al., 2018). For the purposes of this paper it's enough to note that for the past four or so years, Kevin's team and my team have worked to develop and refine a complete dynamical model of the drinking event system. Much of this work has been published in engineering journals (Giraldo, Passino, & Clapp, 2017; Giraldo, Passino, Clapp & Ruderman, 2017; Gonzalez Villasanti, Passino, Clapp & Madden, 2017) with the most accessible piece detailing the conceptual model being Clapp et al., 2018.

Conceptually, this work addressed numerous questions generated by our earlier field work. Over the course of our collaboration, we modeled the various levels of abstraction in our model—pharmacokinetic, psychological, social, and environmental—independently and then finally as a complete system. Our current conceptual work is applying this system to model the impact of potential interventions, guided by empirical literature, relative to variations in the system. For instance, we can estimate the potential effect of price changes in a bar for various types of drinkers, embedded in different types of social networks.

Methodologically, our work has advanced as well. Recently, we conducted three field studies where we followed individual drinkers, or groups of drinkers, to collect data related to all the levels of abstraction noted above. Two of these studies followed college students participating in bar crawls (Clapp, Madden, Mooney, & Dahlquist, 2017). The third study followed groups of friends over a two-week period (Madden & Clapp, in review). These studies used transdermal alcohol monitors, which allow for the repeated biological estimation of consumed ethanol via vapors collected above the skin with sensors, along with GPS monitoring, EMAs, and daily diaries. Not unlike the logic of grounded theory methods, the data collected in these studies are currently being used to "tune" our system dynamic models. In particular, these data will help identify potential leverage points within the system for future intervention. It is important to note that the technologies we are using are not perfect. Transdermal monitors are difficult to interpret.

Taken together, the dynamic modeling stream of work and field studies greatly advance our understanding of drinking events with an eye toward preventing problems. Although our earlier work relied on more standard social science methods and was therefore limited in its conceptual sophistication, it was necessary to inform systems science work. It remains to be seen if this new understanding, brought about by systems thinking, influences the way other researchers conceptualize drinking behavior or design drinking interventions.

In the next phase of our work, our goal is to develop and refine dynamical models and to couple our modeling work with smart monitoring methods in future field studies. Ultimately, we hope to develop "smart" real-time interventions aimed at reducing heavy drinking and acute alcohol problems such as violence and drunk driving. Developing these interventions will require a team science approach with the continued involvement of engineers, computer scientists, and our team of health behavior researchers. The input of community members (in this case drinkers) in the design of smart interventions will be critical as well.

Conclusion and Future Directions

Systems science approaches are a natural extension of the heuristic models we have long embraced in health behavior research and education. Adopting them, however, will require some fundamental changes in the field. If we accept that most health behaviors we hope to change are complex and dynamic (as our heuristic models suggest), we must begin to reexamine our commonly held assumptions about theory, research, and practice (Miller & Page, 2007). If we truly believe the etiologies of health problems are inherently ecological and complex, it follows that theory focusing on a single level of abstraction has limited validity or utility. Practically stated, we need to work more collaboratively with engineers, computer scientists, and the like. As noted above, this work is difficult. Embracing systems science will ultimately change the way we train our students; we will need to include systems thinking, dynamic modeling, and team science in our doctoral curricula. This suggests the older generation of mentors and health behavior scientists working in more traditional streams of research must learn enough to support their peers working in these areas. By extension, tenure processes must recognize the inherent difficulty in carrying out this type of work. Journal editors and reviewers must be flexible enough to embrace studies that do not cleanly fall into traditional research frameworks. Similarly, funders and grant reviewers must do the same. These are large structural changes. It remains to be seen if we are approaching such a paradigm shift in the field.

It is important to note the commercial world is already moving into this space. For instance, smartphone-based “app” developers, like Free Bird, are using sophisticated data analytics to connect bar patrons to ride sharing services. While this likely will reduce driving after drinking, it might increase heavy drinking (Rivara et al., 2007). The market will drive more apps in the future with myriad health implications (see related “mHealth” examples: Kazemi et al., 2017). We cannot afford to be late to this conversation. Indeed, many of these companies are enthusiastic for our input.

In conclusion, I am most grateful for the Academy in helping me facilitate this work through excellent and cutting-edge speakers, a network of supportive and talented colleagues, and a welcoming environment. Without the Academy’s annual meetings, I doubt our earlier work would have advanced to its current state. In that spirit, I hope the ideas presented here stimulate some readers to reexamine the way they approach their own work and ask, *Is this a systems science problem?*

Acknowledgments

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