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**Applying a complex systems perspective to alcohol consumption and the prevention of alcohol-related harms in the 21st century: a scoping review**

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## Abstract

Background and Aims: A complex systems perspective has been advocated to explore multi-faceted factors influencing public health issues, including alcohol consumption and associated harms. This scoping review aimed to identify studies that applied a complex systems perspective to alcohol consumption and the prevention of alcohol-related harms in order to summarise their characteristics and identify evidence gaps.

Methods: Studies published between January 2000 and September 2020 in English were located by searching for terms synonymous with ‘complex systems’ and ‘alcohol’ in the Scopus, MEDLINE, Web of Science and Embase databases, and through handsearching and reference screening of included studies. Data were extracted on each study’s aim, country, population, alcohol topic, system levels, funding, theory, methods, data sources, timeframes, system modifications and type of findings produced.

Results: Eighty-seven individual studies and three systematic reviews were identified, the majority of which were conducted in the United States or Australia in the general population, university students or adolescents. Studies explored types and patterns of consumption behaviour and the local environments in which alcohol is consumed. Most studies focused on individual and local interactions and influences, with fewer examples exploring the relationships between these and regional, national and international sub-systems. The body of literature is methodologically diverse and includes theory-led approaches, dynamic simulation models and social network analyses. The systematic reviews focussed on primary network studies.

Conclusions: The use of a complex systems perspective has provided a variety of ways of conceptualising and analysing alcohol use and harm prevention efforts, but its focus ultimately has remained on predominantly individual- and/or local-level systems. A complex systems perspective represents an opportunity to address this gap by also considering the vertical dimensions that constrain, shape and influence alcohol consumption and related harms, but the literature to date has not fully captured this potential.

Key words: complex systems, alcohol consumption, alcohol harms, prevention, scoping review, dynamic simulation modelling, social network analyses

## Introduction

Alcohol consumption and associated harms represent a complex public health issue that affect individuals, communities and nations1. Alcohol is the seventh largest risk factor for disability and premature death worldwide and contributes to noncommunicable and infectious diseases2. The harms associated with alcohol affect individuals through acute and chronic conditions, as well as their families and broader communities, through, for example, domestic abuse and neglect, adverse effects on relationships, anti-social behaviour, violence, crime and workplace productivity losses1,3-9. Such alcohol-related harms are not evenly distributed across populations; individuals with lower socioeconomic status (SES) tend to experience greater alcohol-associated harms compared to those with a higher SES, despite similar or lower levels of alcohol consumption10.

A public health approach to alcohol harm prevention emphasises a combination of targeted interventions for high-risk drinkers, changing population behaviours and addressing their upstream determinants11-13. The application of a ‘complex systems perspective’ to alcohol research brings an explicit focus to how micro, meso and macro determinants interact with each other between and across system levels to create alcohol harms. Complex systems are characterised by non-linearity and feedback loops; changes within the system may result in larger or smaller impacts depending on how the system adapts in ways to amplify or dampen the effects14,15. These responses may be unpredictable, leading to unanticipated impacts16. A complex system evolves over time and can be characterised by emergent properties, a sort of ‘collective behaviour’ that cannot be reduced to individual actors’ behaviour14,17-19.

A complex systems perspective, therefore, focuses on the dynamic and evolving relationships between actors within a system, and between the system and its broader environment20. Rather than focusing on individuals, or even specific sub-population or population groups, a key tenet of a complex systems perspective is recognising the broader systemic factors that influence populations and individuals’ behaviour15 with a specific emphasis on interactions between system levels and elements21. A population-perspective is therefore not necessarily a complex systems perspective; in the latter, the system is the primary unit of inquiry.

A number of researchers have argued that public health alcohol research would benefit from a paradigm shift: one that forefronts the real-world systems in which alcohol consumption and harms are created and shaped by a complex web of interrelating factors22-24. Proponents argue that most alcohol research is reductionist, being too focused on high-risk populations, individual-level (e.g. behavioural and psychological) or easily modifiable risk factors while failing to account for the dynamic and interrelated factors within the social, cultural, economic, regulatory, political and physical environments in which alcohol is consumed and harms are experienced25-28. Alcohol prevention efforts may therefore prove ultimately ineffective22,23, or be misleading24, if they rely solely on traditional epidemiological methods that assume linear causal pathways22,23. Utilising a complex systems perspective could, in principle, allow policymakers to develop strategies that intervene across the numerous systems that influence alcohol-related harms26,28-31. Some researchers have embraced this approach, but to date, no review has systematically documented these efforts. We therefore conducted a scoping review32-35 to characterise how a complex systems perspective has been applied to research on alcohol consumption and the prevention of alcohol-related harms.

A scoping review is used to assess the size and scope of a literature base in order to assess its characteristics and identify evidence gaps33,35. In contrast with a systematic review, a scoping review does not aim to appraise and synthesise the literature, and it was therefore not an aim to combine the results of the identified studies35.Within our broad aim, we focused on four research questions: 1) which public health alcohol topics have had a complex systems perspective applied to them? 2) what systems of inquiry and populations are represented? 3) what types of systems approaches have been utilised? and 4) what gaps remain?

## Methods

We conducted a scoping review, following Arksey and O’Malley’s framework: 1) identifying and refining research questions and the review’s scope (defined above); 2) identifying studies; 3) selecting studies; 4) charting the data; and 5) collating, summarising and reporting the results32. The protocol for the review is available in Supplementary Material 1 and was not pre-registered.

### Identifying relevant studies

Relevant studies were identified through searches in electronic databases, handsearching and screening the references of included studies. Electronic searching was conducted in Scopus, MEDLINE, Web of Science and Embase covering January 2000 – September 2020, using terms and synonyms for complex systems and alcohol. The search dates reflect the increased interest in complex systems and public health in the 21st century36. The search strategy can be found in Supplementary Material 2.

### Study selection

Studies were eligible for inclusion if they: 1) took an approach that was informed by a complex systems perspective; 2) primarily concerned alcohol consumption and/or the prevention of alcohol harms from a public health perspective; and 3) were published between January 2000 and September 2020 in English. Papers applying a socio-ecological model, which considers individuals’ behaviour and health outcomes as being situated within multi-scale social environments37, were excluded, unless the authors explicitly considered interactions between system levels and elements. Public health relevance was conceptualised broadly and included studies that explicitly advocated, developed or evaluated prevention efforts, as well as papers which developed theoretical or causal models of alcohol consumption and/or related harms. Articles about alcohol’s effect on individuals’ physiological systems, treatment for alcohol-related disorders and studies conducted in animals were excluded. Protocols, commentaries and conference abstracts were excluded, although full conference papers were eligible for inclusion.

We identified three recent systematic reviews that explored the association between social network characteristics and processes and alcohol consumption in adolescents38,39 and adults40. Instead of duplicating these efforts, we decided to exclude individual network studies and focus on the findings from these three reviews as they relate to our review questions.

Titles and abstracts were initially screened for inclusion and the full text of all potentially relevant studies were then reviewed; EM conducted the screening and MM independently screened 10% of the titles/abstracts and full text studies. Covidence software was used to facilitate the screening process41.

### Charting the data

Charting the data was an iterative process and the template we designed was revised during the extraction process to better capture relevant data34. EM and CR independently extracted data on 10% of studies to pilot and revise the template; EM extracted data from the remainder of publications. We counted each individual published article we identified as a study, even if multiple papers where written by the same authors and/or utilised the same underlying models in order to identify what it might add to the discourse on how a complex systems perspective is advocated and applied to alcohol research.

We extracted data on each study’s aim, country, population(s), alcohol topic(s), system levels, funders, theory, methods, data sources, timeframes, system modifications and types of findings produced. We conceptualised five broad system levels: sub-local, local, regional, national and international. Broadly, we considered sub-local systems to contain individuals, their family, friends and social networks. Local systems may vary greatly in scale but we used the term to refer neighbourhoods, towns or cities. We conceptualised regional systems as being on a larger geographical scale, such as states, provinces or regions. System modifications refer to any planned system change – hypothetical or implemented, including policies, interventions or services. The types of findings referred to a characterisation of the study’s results, rather than the specific conclusions; this included, for example, arguments for a specific approach, simulated impacts of an intervention, or findings from a process evaluation. As this was a scoping review that aimed to understand the scope and scale of the literature, no formal quality appraisal tool was applied to the included studies32,34,35.

### Collating and summarising

Keeping with our aim, we then analysed the extracted data to produce a descriptive summary of the characteristics of the included studies, which we present in both tabular (Tables 1-4) and narrative form32. Then, using the research questions as a guide to our analysis, we synthesised the means by which a complex systems perspective has been utilised in alcohol consumption and harm prevention research.

## Results

A total of 87 individual studies were identified for inclusion in this scoping review; in addition, we identified three systematic reviews on network effects on alcohol consumption (see Figure 1). Tables 1 and 2 present an overview of the characteristics of each of the individual identified studies, grouped by complex systems approach and denote which papers belong in a cluster. The characteristics of the systematic reviews are presented in Table 4 and we report on those separately at the end of the Results.



The studies we identified conceptualised, described or modelled systems of interest to alcohol-harm prevention research primarily in the United States (US) (n=38)22,23,29,42-76, Australia (n=17)28,31,77-91, and the United Kingdom (UK) (n=7)26,92-97. We also found examples of generic alcohol systems (n=16)24,93,98-111, as well as examples from Sweden (n=2)112,113, South Africa (n=2)114,115, Canada (n=1)116, Denmark (n=1)117, Nepal (n=1)118 the Netherlands (n=1)119, and South Korea (n=1)120.

**Insert Tables 1 and 2 approximately here**

### Populations of interest

A range of population groups were represented within the systems and some studies focused on more than one population of interest. Thirty-nine studies included the general population24,26,28,31,42,43,45,47,49,51,57,59,70,71,73-77,87-91,97-101,103,105,108-112,116,118,119. Studies also focused specifically on university students (n=14)22,23,44,48,58,60-64,66-68,104, adolescents (n=12)29,52,54-56,69,72,79,107,113,115,120, younger adults (n=10)50,72,78,79,81,83,84,92,96,120, heavy drinkers (N=5)45,46,78,83,84, older adults (n=1)46 and persons with substance use disorders (n=4)56,65,102,114, as well as more specifically defined groups including sporting club administrators and participants80, street drinkers95 and American Indian adoptees53. Some studies focused on those who work within the alcohol and drug workforce57,85,86,94,106. Other studies included alcohol retailers and the alcohol industry24,82,93,95,103,112, as well as policymakers and different types of organisations80,82,121.

### Alcohol topics

The identified studies focused on different facets of alcohol from a public health perspective. Many studies were concerned with alcohol consumption42,44,45,49,50,52,54,55,60,69,72,77,79,92,101,103,107,113,115,117,118,120, including specific types of consumption, such as intoxication73,78,99, alcohol misuse22,23,29,46,56,100,114, binge drinking26,96,104,119 or particular patterns, types and contexts of drinking43,48,51,58,59,61-64,66-68,74-76,81,98,105. Some studies considered the impact of those consumption patterns, including acute and chronic health and social harms to individual drinkers and those in their communities28,31,46,49,70,71,85,87-90,108,109,111, including, for example, mental health outcomes53,65,110, aggression78,83,84, injuries and violence42,45,57,87,97,112,116. Other studies explored the influence of the environments in which alcohol is regulated, sold and consumed, including characteristics and density of alcohol retailing outlets28,42,43,45,47,51,57,66,68,70,71,77,78,80,82,83,87,95,103,108,112,116, transportation policies and regulation47,70,71,84,91,108,109 and multinational commercial interests and practices that seek to influence regulation, social norms and drinking environments24,93,121. Finally, a small group of studies looked at the development and practices of the alcohol workforce86,94,102,106.

### System levels of interest

The studies we identified described systems that could be categorised as sub-local, local, regional, national or international; or systems that included elements that belonged to more than one of these levels. Studies that considered only one system level primarily focused on the sub-local often considering social influences on individuals’ drinking behaviours44,50,52,53,55,56,64,65,92,96,104,107,114,117,119. We also identified examples that focused solely on local51,57,70,71,79,86,100,108,109,111-113,116, regional47 and national85,121 systems. Studies focusing on sub-local or local systems varied in their timeframes; for example one study used an agent-based model (ABM) to generate an in-depth understanding of how drinking evolves over the course of a single evening in response to peer influences64 whereas another ABM explored the impact of alcohol taxation policies and social connectedness interventions on depression and alcohol misuse amongst older adults over five years46.

While the majority (n=56) of the studies included more than one system level in their analysis22-24,26,28,29,31,42,43,45,46,48,49,54,58-63,66-69,72-78,80-84,87-91,93-95,97-99,101-103,105,106,110,115,118,120, most researchers limited this analysis to two systems, usually the sub-local and local. Some authors focused primarily on elements within the sub-local system and included a single broader ‘cultural’ element69,72,120. Other researchers, particularly those creating dynamic simulation models, sought to understand how individuals respond and are influenced by environmental characteristics, and how these responses influence others within the system over time. For example, some ABMs simulated the impact of taxation on alcohol consumption and violent victimisation in one city45 or changes in public transport hours on verbal aggression84; another study informed by complexity theory considered the ways in which a retailer intervention reducing local alcohol availability could result in individuals engaging in different substitution behaviours95.

We identified some studies that explored relationships between system elements at more than two levels22,24,60,74-76,80,82,91,93,94,103,105,106,115,118. For example, one analysis considered the ways in which the practices of multinational corporations who manufacture, advertise, and sell unhealthy commodities such as alcohol, seek to influence public health policy and regulation which shapes broader cultural norms and local environments, ultimately affecting individuals’ alcohol consumption93.

We had planned to analyse variation in studies based on funding, but identified only one paper that reported funds from an organisation that receives funding from the alcohol industry79.

### Complex systems approaches

The identified studies utilised a range of complex systems approaches, which we grouped into: 1) theory-led approaches and 2) dynamic simulation modelling.

#### Theory-led approaches

Forty-one studies were identified that can be broadly classified as ‘theory-led approaches’ to preventing alcohol-related harms from a complex systems perspective. Table 3 gives a description of the theories and their application in this literature. Twelve studies reported being informed by systems theory57,71,80,85,102,106,108,109,112,113,117,118, which authors also referred to as systems thinking, a systems perspective or a systems approach. Systems theory was used to either inform prevention approaches, or to analyse interventions from a systems perspective. These papers included Harold Holder’s seminal work on community alcohol systems, wherein a community is conceptualised as giving rise to alcohol consumption and associated harms, therefore necessitating a systems approach to prevention which focuses on understanding the relationships between many influences on drinking70,71. Ten studies, also drew on insights from complexity science24,93,108,109,111, with some explicit applications of complexity theory79,82,86,95. Eleven studies were informed by ecological systems theories49-51,54,69,72,94,103,110,115,120, including one that developed a behavioural ecological model of alcohol consumption49 and another that created a developmental ecological model of alcoholism110. Five studies applied family systems theory52,53,55,56,114 and the two final theory-led approaches we identified included theories of practice105 and information theory47.

**Insert Table 3 approximately here**

A range of different data collection methods were used in the theory-led approaches. Data were generated in many studies through qualitative methods, including interviews79,80,82,86,95,112,114,115,117,118, focus groups82,95,115,118, journal entries117, documentary review86,121, media analyses121, observations82, sense-making workshops118 and participatory mapping exercises29. A number of the theory-led approaches conducted survey research47,51,53,56,79,82,113 52,54,55,69, either designing and utilising new tools, using validated scales, or drawing on secondary data sets. A number of authors conducted literature reviews, both systematic72,120and non-systematic24,49,70,71,93,94,102,103,105,106,108-111 . One study conducted response-to-scenarios research50 and two others presented descriptions of programmes57,85, informed by programme data.

#### Dynamic simulation modelling

We identified 46 papers which advocated for, or conducted, dynamic simulation modelling. These refer to computational models which model non-linear causal relationships between system elements, which may operate at varying temporal and spatial scales in order to understand emergent patterns of system behaviour 22,31. The majority of the dynamic simulations we identified described the process of developing, or developed, ABMs (n=29)28,31,42-46,58,60,62,64,74-78,81,83,84,87-90,92,96-98,107,119 or advocated for the use of, or developed, system dynamics (SD) models for alcohol-harm prevention (n=9)22,23,26,59,60,73,91,99,100. ABMs model individual agents with different personal characteristics who interact with other agents according to ‘rules’ that govern their behaviour within a specific environment42,83 SD models represent the interrelationships between system elements and how behaviour is governed through feedback loops. In contrast to ABMs, SDs focus less on individual agents and more on “population-level influences and whole-system dynamics”31 p.2. ABMs and SD models have been utilised to understand the dynamics of individual and social drinking behaviour44,64,74-76,81,92,96,99,107,119, to explore how individuals and their networks interact with their broader environment22,23,43,59,97,98 and to predict outcomes stemming from the introduction of an intervention or range of policy options26,28,31,42,45,46,58,62,73,77,78,83,84,87-91.

We also identified compartmental models which were developed and extended by two research groups interested in exploring the dynamics of drinking behaviours in university students48,61-63,66-68. Two cellular automata models were developed which compare the effects of alcohol outlet density on violent offending116 and to understand how social interaction influences binge drinking in students104. Finally, we identified one cusp catastrophe model which modelled the dynamics of relapse65.

The dynamic simulation models varied in regard to the degree to which they developed their underlying conceptual models and the extent to which these models were informed by theory or empirical data. Several models were explicitly theory-led43,58,64,65,74-76,92,116, whereas the majority drew on implicit theories. Most of the theories informing models were individual-level and concerned individuals’ behaviours, particularly peer and social influences on alcohol consumption58,59,64,65,81,92,96,98,104,107,119. However, some studies theorised that drinking environments or societal norms and roles may also influence consumption and alcohol-related harms42,43,74-76. A large number of the models drew on empirical data, both primary65,81,96 and secondary data from a range of sources, including academic literature28,31,44,46,48,61-63,73,78,81,83,84,87,91,97,99,104,116, censuses42,45,75,76, cohort studies, surveys and local and national data from public agencies26,28,31,42,43,45,46,48,60-63,66-68,74-76,78,81,83,84,87,91,92,97,104,116,119. Apostolopoulos et al advocated for participatory model building23 and we identified one model that used stakeholder engagement in the model building process28,31,87-90.

#### Social network analyses

Three recent systematic reviews primarily identified studies conducted in the US examining the influence of social networks on adult40 and adolescent38,39 alcohol use. Knox and colleagues identified 17 studies which explored the association between the characteristics of network members or characteristics of the network structure on adult alcohol consumption outcomes40. The majority of the studies were conducted in adults under the age of 30 and in university settings40. Montgomery and colleagues reviewed studies which explored the association of homophilic social selection, social influence, popularity and network structure on adolescent drinking (n=17) or drinking and smoking (n=7)38. A third systematic review conducted by Henneberger and colleagues reviewed stochastic actor-based models to explore the effects of peer selection and peer socialisation processes on adolescent alcohol (n=21), tobacco (n=23) or drug use (n=6)39. Stochastic actor-based models are dynamic and were used in the identified studies to model peer selection and socialisation impacts after controlling for network and behavioural characteristics39. Some studies were included in both the Montgomery et al38 and Henneberger et al39 reviews. The studies identified in the three reviews conducted analyses of sub-local systems, with an emphasis on the relationship between aspects of social networks and consumption. The included social network analyses drew on theories of social influence on drinking behaviour and utilised primary and secondary cross-sectional and longitudinal survey data.

**Insert Table 4 approximately here**

## Discussion

We identified a large number of studies applying a complex systems perspective to alcohol consumption and the prevention of alcohol-associated harms. Studies examine diverse facets of alcohol, considering both types and patterns of consumption behaviour and the (mostly) local environments in which alcohol is purchased and consumed. The body of literature is methodologically diverse, with examples of theory-led approaches incorporating a range of study design, as well as dynamic simulation modelling. There is also a large body of research exploring network influences on alcohol use.

A key finding of this review is that alcohol systems research tends to focus on individuals and small-scale local systems. A complex systems perspective calls for broader systemic-level analysis and intervention, but the application of this remains underdeveloped – even in studies that take a systems-informed approach. We found few examples of how the local environment is shaped by broader system levels – that is, regional, national and international forces that influence it. This finding mirrors that of a systematic review on the use of ABMs and SD models in obesity research which found that most models focused on individuals, their networks and local environments, with far fewer considering meso- and macro-systems122.

Bambra and colleagues have argued that traditional (i.e. not explicitly systems-oriented) place-based research on health inequalities has tended to focus on the individual or the local, while largely ignoring the political and economic forces that influence local policies and environments123. Bambra et al. contend that researchers have an obligation to widen their lens or to “scale up” – to move beyond *horizontal* (i.e. local)explanations to *vertical* (i.e. macro/national) explanations – in order to analyse the “complex multi-scalular and interdependent processes operating at the systems level”123 p.37. Failing to do so, they argue, means that interventions, will ultimately remain local, while failing to address systemic drivers of health and health inequalities.

The findings from this scoping review lead us to make a similar argument and conclusion for alcohol research. Many of the theories that underpin the public health evidence base are individual-level15, and this applies to many of these studies identified in this review which focus on the behavioural and psychological factors that influence consumption and the distribution of alcohol harms22,24. Such individual risk factors are often perceived as being more easily modifiable that meso- and macro- systemic structures22. Many of the studies identified in this review also focused on the local level, which may reflect the tendency to implement local-level interventions to address alcohol-related harms100. Three reviews of social network effects on alcohol consumption reinforce this observed tendency to focus on sub-local and local systems38-40 .

In order to theorise and design effective alcohol harm reduction efforts, alcohol systems researchers should consider how to move beyond the individual22 and the local, and consider the broader systemic levels that shape alcohol-related harm24 – a shift of focus from horizontal complexity to vertical complexity. These broader systemic levels might include, for example, the influence multinational alcohol industry actors exert on drinking culture through marketing and licensing; as well as how the industry influences individual attitudes and drinking practices through misinformation and lobbying at the macro and micro levels124,125. We identified some examples of this, and we recognise that this is not without its challenges, including a possible trade-off of depth for breadth95.

*Limitations and challenges*

The nature of our search strategy meant that we may have missed studies which are compatible with a complex systems lens, but do not use the associated terminology. A review of Canadian health promotion efforts on alcohol and tobacco use found that evaluations frequently assessed aspects of complexity without engaging with the complexity literature20. In addition, due to the nebulous terminology associated with complex systems, studies which may be methodologically relevant but do not utilise the terms we used in our search strategy, may have been missed. By relying on systematic reviews of individual network studies, we may have also missed studies that were not captured by those review’s search strategies, including studies published after the review’s search dates. We also did not include studies published prior to 2000 which excludes earlier applications of a complex systems perspective to alcohol research. A previous review also highlighted that much of the complex systems research is presented at conferences17. While we did identify some full conference papers, there may be other work in this area that we did not identify. We also only searched for English-language publications.

This literature base is diverse and it can be challenging to conceptually group studies with different aims, approaches, methods and data sources. Some papers we identified were based on the same (or similar) models, which researchers revised overtime88 and used to test different scenarios26, driven by evidentiary needs 126. This presents a challenge for evidence synthesis regarding how to account for multiple outputs from one model. In some instances, usual guidance on ‘linked’ reports 127 may be insufficient.

## Conclusion

The use of a complex systems perspective has provided a variety of ways of conceptualising and analysing alcohol use and harm prevention efforts, but it has ultimately not transformed its overall focus, which remains predominantly on the individual or local level. In 2004, Gorman and colleagues argued it is logical that alcohol research focuses on community-level systems; many alcohol interventions are implemented locally and local systems represent a good balance between the simple and complex for a dynamic model. They went on to argue that “whether community-level systems represent the optimal scale for modelling and controlling illicit drug use and misuse (as well as alcohol use-related outcomes) remains to be seen through empirical research.”100 p.1726 Sixteen years on, there remain relatively few examples of empirical research that have moved beyond the individual and local level to answer this challenge. A complex systems perspective represents an opportunity to consider the vertical dimensions that constrain, shape and influence alcohol consumption and related harms, but the literature to date has not fully captured this potential. We recommend alcohol researchers rise to this challenge and explore the multiple and interacting horizontal and vertical factors that influence alcohol consumption and the distribution of alcohol-associated harms.

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**Table 1: Study characteristics; theory-led approaches**

| Authors and Year  *Title* | Aim | Country. (Population). Alcohol topic | System level(s) | Theory. (Methods). Timeframe | System modifications examined | Types of findings |
| --- | --- | --- | --- | --- | --- | --- |
| Anderson et al 2016 47  *Understanding policy diffusion in the U.S.: An information-theoretical approach to unveil connectivity structures in slowly evolving complex systems* | To measure the existence and direction of influence of one state’s policy or legal activity on others with regards to alcohol, driving safety and impaired driving regulation in the US. | US. (General population). Alcohol regulation and availability; impaired driving regulation | Regional | Information theory. (Information-theoretical framework and a stochastic model for validation). 1980-2000 | Enactment and changes to alcohol availability regulation and driving laws | Factors that influence policy diffusion and adoption |
| BeLue et al 2012 29  *Systems thinking tools as applied to community-based participatory research: a case study* | To illustrate the use of systems thinking in a community-based participatory research framework using a case study of a community coalition that addresses problem drinking among adolescents. | US. (Adolescent high school students). Youth alcohol misuse and prevention | Multiple: sub-local and local | Systems thinking; complex adaptive systems. (Participatory research; causal loop diagram exercise). Duration of initiative (unspecified) | None | Argument for use of approach; influences on drinking |
| Birckmayer 2004 49 \*  *A general causal model to guide alcohol, tobacco, and illicit drug prevention: Assessing the research evidence* | To develop an alcohol, tobacco and other drugs (ATOD) causal model that seeks to identify the variables that are theoretically salient and empirically connected across alcohol, tobacco, and illicit drugs. | US. (General population). Alcohol use and associated harms | Multiple: sub-local and local | Complex systems model. (Non-systematic literature review). Unspecified | None | Development of model |
| Bogg and Finn 2009 50  *An ecologically based model of alcohol-consumption decision making: evidence for the discriminative and predictive role of contextual reward and punishment information* | To develop and test an assessment of alcohol-consumption decision making guided by insights from ecological systems theory and reinforcement sensitivity theory. | US. (Young adults aged 18-30). Alcohol consumption | Sub-local | Bronfenbrenner’s ecological systems theory; reinforcement sensitivity  theory. (Response to scenarios). Week | None | Influences on drinking |
| Brennan et al 2016 101  *Social marketing’s consumer myopia: applying a behavioural ecological model to address wicked problems* | To describe a behavioural ecological systems approach to enhance understanding of social markets. | Generic. (General population). Alcohol consumption; sales | Multiple: local and national | Behavioural ecological systems theory. (Non-systematic literature review). Unspecified | None | Argument for approach; development of model; influences on drinking |
| Chun et al 2013 69  *Psychoecological model of alcohol use in Mexican American adolescents* | To propose and test a structural model based on Bronfenbrenner’s ecological systems theory to understand alcohol use among Hispanic adolescents. | US. (Hispanic adolescents).  Adolescent alcohol consumption | Multiple: sub-local and national | Ecological systems theory. (Cross-sectional survey design with validated questionnaires). Unspecified | None | Development and testing of model |
| Galvani et al 2017 94  *Social work and substance use: ecological perspectives on workforce development* | To offer a theoretical analysis of the extent to which social work structures and systems support social workers to work effectively with people using substances problematically. | UK. (Social workers). Social work education and practice | Multiple: sub-local, local and national | Bronfenbrenner ecological systems theory. (Non-systematic literature review). Unspecified | None | Influences on social work practice |
| Gruenwald 2007 103 †  *The spatial ecology of alcohol problems: niche theory and assortative drinking* | To summarise theoretical perspectives that explain associations between  concentrations of alcohol outlets and alcohol-related problems; to propose a conceptual model of  the social ecology of alcohol use. | Generic. (General population, commercial actors). Alcohol consumption; outlet density; outlet characteristics; commercial interests | Multiple: sub-local, local, national and international | Niche theory; assortative drinking; social ecology theory. (Non-systematic literature review). Unspecified | None | Development of theoretical model |
| Gruenwald et al 2014 51 †  *Testing a social ecological model of alcohol use: the California 50‐city study* | To assess relationships between demographic and personality characteristics of individual drinkers and environmental characteristics at the city level to measures of drinking patterns and use of drinking contexts. | US. (General population). Drinking patterns; drinking contexts; outlet density | Local | Social ecology theory. (Archival and survey data from 50 cities). Single time point | None | Environmental influences on drinking |
| Haggard et al 2015 112  *Implementation of a multicomponent Responsible Beverage Service programme in Sweden - a qualitative study of promoting and hindering factors* | To identify factors that either promote or hinder implementation of a multicomponent Responsible Beverage Service programme in Swedish municipalities. | Sweden. (General population, bar staff). Responsible beverage services; violence and injuries | Local | Systems thinking. (Semi-structured interviews). Single time point | Responsible Beverage Service programme | Process evaluation findings |
| Hlomani-Nyawasha et al 2020 115  *Factors influencing alcohol use among female in-school adolescents in the Western Cape, South Africa* | To explore the factors influencing alcohol use among female adolescent students as guided by the ecological systems theory of Bronfenbrenner. | South Africa. (Female adolescents). Alcohol consumption | Multiple: sub-local, local, national | Bronfenbrenner ecological systems theory. (Semi-structured interviews; focus groups). Single time point | None | Multi-level influences on drinking |
| Holder 2001 108 \*  *Prevention of alcohol problems in the 21st Century: challenges and opportunities* | To describe a systems approach to substance abuse treatment and prevention and to present findings from a systems-informed community system prevention effort. | Generic. (General population). Community mobilisation; drink driving; responsible beverage service; underage drinking; retailer density and characteristics | Local | Systems approach. (Non-systematic literature review). Unspecified | Drink driving laws; changes to alcohol availability; responsible beverage service; underage drinking policies; enforcement | Argument for approach; evaluation results |
| Holder 2001 71 \*  *Community prevention trials: a respectful partnership.* | To review the theoretical basis for a systems approach to community prevention and to evaluate a systems-informed intervention. | US. (General population).  See Holder 2001 108 | Local | Systems approach. (Non-systematic literature review). Unspecified | See Holder 2001 108 | Argument for approach; evaluation results |
| Holder 2002 70 \*  *Prevention of alcohol and drug “abuse” problems at the community level: What research tells us* | To present an alternative model for reducing alcohol-involved  problems at the local level and a review of research  evidence about effectiveness. | US. (General population). See Holder 2001 108 | Local | Systems approach and complex adaptive systems. (Non-systematic literature review). Unspecified | See Holder 2001 108 | Argument for and illustration of approach |
| Holder et al 2005 111 \*  *Community systems and ecologies of alcohol problems* | To outline the theoretical bases underlying the community systems approach to alcohol and to introduce the application in computer modelling. | Generic. (General population). Alcohol problems and prevention | Local | Complex systems / systems approach. (Non-systematic literature review). Unspecified | Drink driving interventions | Argument for approach; illustration of approaches |
| Holder 2010 109 \*  *Substance abuse treatment as part of a total system of community response* | To present a systems approach to substance abuse treatment and prevention. | Generic. (General population; high risk drinkers; individuals with substance-based disorders).  Substance abuse prevention and treatment; alcohol-related traffic injuries | Local | Systems approach. (Non-systematic literature review). Unspecified | Multiple - example of preventing alcohol-related motor vehicle crashes | Development of system model |
| Hong et al 2011 72  *Substance abuse among Asian American youth: An ecological review of the literature* | To understand the risk and protective factors that are associated with substance use among Asian American youth, using Bronfenbrenner's ecological systems theory. | US. (Asian American adolescents and young adults age 10-24).  Alcohol consumption | Multiple: sub-local and national | Bronfenbrenner's ecological systems theory. (Systematic literature review). Unspecified | None | Risk and protective factors for drinking |
| Hong et al 2011120  *Alcohol and tobacco use among South Korean adolescents: An ecological review of the literature* | To review existing studies on the risk factors for alcohol and tobacco abuse among South Korean adolescents within the context of ecological systems theory. | South Korea. (Adolescents and young adults age 10-24). Alcohol consumption | Multiple: sub-local and national | Bronfenbrenner's ecological systems theory. (Systematic literature review). Unspecified | None | Prevalence of alcohol use; risk and protective factors for drinking |
| Kelly et al 2011 79  *Charismatic cops, patriarchs and a few good women: Leadership, club culture and young peoples' drinking* | To examine the roles that community-based sporting clubs in the Australian state of Victoria play in shaping young people’s understandings and uses of alcohol. | Australia. (Adolescents young adults involved in sports clubs aged 14-24). Adolescent alcohol consumption; alcohol environments | Local | Complexity science; complex adaptive systems. (Interviews). Single time point | None | Argument for approach; influences on environment and drinking |
| Knai et al 2018 121  *The Public Health Responsibility Deal: using a systems-level analysis to understand the lack of impact on alcohol, food, physical activity, and workplace health sub-systems* | To use a systems approach to make sense of the evaluative findings of the UK's Responsibility Deal in order to explore why the initiative did not reach its objectives. | UK. (Organisations in public, private and third sector). Voluntary pledges to improve public health | Multiple: sub-local, local, national and international | Systems approach. (Literature review; interviews; case studies with interviews and document review; media analysis; adherence to pledges). 3 years | Voluntary organisational commitments within a public-private partnership framework | Process evaluation findings |
| Knai et al 2018 93  *Systems thinking as a framework for analyzing commercial determinants of health* | To use a complex systems perspective to analyse the commercial determinants of NCDs; to (1) conceptualise the problem of NCDs and (2) develop effective policy interventions. | Generic. (Corporate actors). Commercial determinants | Multiple: sub-local, local, national, international | Systems thinking; complex systems. (Non-systematic literature review). Unspecified | None | Argument for, and worked example, of approach |
| Knauth et al 2006 52  *Effect of differentiation of self on adolescent risk behaviour: test of the theoretical model* | To test the credibility of a theoretical model based on the Bowen family systems theory to explain adolescent risk behaviour. | US. (Adolescents age 14-19). Adolescent alcohol use | Sub-local | Family systems theory. (Cross sectional survey using validated questionnaires). Single time point | None | Development and testing of model |
| Kühn and Slabbert 2017 114  *The effects of a father's alcohol misuse on the wellbeing of his family: views of social workers* | To explore and describe the effects of alcohol misuse by a father on the wellbeing of his family, as viewed by social workers. | South Africa. (Fathers who misuse alcohol). Alcohol misuse | Sub-local | Family systems theory. (Interviews). Single time point | None | Effects of alcohol misuse |
| Landers et al 2017 53  *American Indian and White adoptees: are there mental health differences?* | To explore the presence of mental health problems of American Indian persons compared to White persons who were separated from their birth families during childhood. | US. (American Indian adoptees). Alcohol addiction and recovery | Sub-local | Family systems theory; attachment theory. (Questionnaire). Single time point | None | Predictors of alcohol addiction and recovery |
| MacLean et al 2013 86  *Factors contributing to the sustainability of alcohol and other drug interventions in Australian community health settings* | To identify factors that support the sustainability of interventions implemented to enhance responses to alcohol and other drug misuse in Australian community health settings. | Australia. (Alcohol and drug workforce). Alcohol intervention sustainability | Local | Complexity theory. (Interviews; documentary analysis). Varied; up to 6 years | Enhancing organisational systems and processes; workforce development; community education | Process evaluation findings |
| McGill et al 2016 95  *Consequences of removing cheap, super-strength beer and cider: a qualitative study of a UK local alcohol availability intervention* | To use a systems perspective to qualitatively explore how Reducing the Strength may lead to intended and unintended consequences within the system in which it was implemented. | UK. (Consumers of super-strength beers and ciders; retailers). Alcohol availability and consumption;  street drinking; voluntary initiatives | Multiple: sub-local and local | Systems thinking; complexity theory. (Interviews; focus group). Single time point | Removal of a particular type of drink | Process evaluation findings |
| Meier et al 2018 105  *All drinking is not equal: How a social practice theory lens could enhance public health research on alcohol and other health behaviours* | To call for a new approach to alcohol epidemiology and intervention research informed by theories of practice | Generic. (General population). Drinking practices | Multiple: sub-local, local and national | Theories of practice. (Non-systematic literature review). Unspecified | None | Argument for theoretical approach |
| Nygaard 2001 117  *Intervention in social networks: A new method in the prevention of alcohol-related problems* | To present the method, findings, and perspectives of a project based on systems theory aiming at preventing alcohol-related problems through intervention in social networks. | Denmark. (Adult 'social drinkers'). Alcohol consumption | Sub-local | Systems theory. (Interviews; journal entries). Two waves; 6 months apart | Encouraging abstinence from alcohol consumption | Impacts of the intervention |
| Petticrew et al 2017 24  *Alcohol advertising and public health: Systems perspectives versus narrow perspectives* | To challenge overreliance on narrow forms of evidence and approaches to investigating causality to inform decision-making and to advocate for a new framework for alcohol research that takes a broader systems perspective. | Generic. (General population, alcohol industry actors). Alcohol advertising | Multiple: sub-local, local, national and international | Systems perspectives; complex systems. (Non-systematic literature review). Unspecified | None | Argument for approach |
| Roche and Nicholas 2017 106  *Workforce development: An important paradigm shift for the alcohol and other drugs sector* | To describe and outline the implications of a major paradigm  shift in the conceptualisation of alcohol and drug (AOD) workforce development that embraces a systems perspective. | Generic. (AOD workforce). Workforce for prevention and treatment AOD | Multiple: sub-local, local, national and international | Systems approach. (Non-systematic literature review). Unspecified | Workforce restructuring | Argument and description of approach |
| Rowe and Bavinton 2011 82  *Tender for the night: after-dark cultural complexities in the night-time economy* | To addresses the confusing, contradictory influence of a  polarized night-time economy policy agenda and expose the contrasting multi-layered complexities of the diverse cultural practices of urban nightlife. | Australia. (Users and components of the night time economy). Nightlife culture | Multiple: sub-local, local and regional | Complexity theory. (Interviews; focus groups; observations; online questionnaire). 2 years | Policies approaches to the night-time economy | Argument for theoretical approach |
| Sharma et al 2020 118  *The role of tobacco and alcohol use in the interaction of social determinants of non-communicable diseases in Nepal: a systems perspective* | To describe the role of tobacco and alcohol use in the interaction of social determinants of NCDs in Nepal. | Nepal. (General population). Alcohol consumption | Multiple: local, regional, national, international | Systems approach. (Key informant interviews; focus groups; sense-making sessions; qualitative system dynamics). | None | Interaction between social determinants of health and alcohol use |
| Simoneau and Bergeron 2000 110  *An etiologic model of alcoholism from a developmental ecological perspective* | To create an etiologic model of alcoholism over an individual's lifespan. | Generic. (General population). Alcohol dependence | Multiple: sub-local and national | Developmental ecological perspective. (Non-systematic literature review). Life course | None | Development of conceptual model |
| Sipsma et al 2012 54  *Future expectations among adolescents: a latent class analysis* | To investigate whether an empirically-driven, multidimensional approach to conceptualizing future expectations can substantively contribute to our understanding of adolescent risk behaviour. | US. (Adolescents age 15+). Alcohol consumption | Multiple: sub-local and local | Bronfenbrenner’s ecological systems theory. (Data from longitudinal survey). Single time point | None | Probability of becoming intoxicated |
| Soloski et al 2016 55  *Gender differences: emotional distress as an indirect effect between family cohesion and adolescent alcohol use* | To explore the relationship between family cohesion, emotional distress, and adolescent alcohol use. | US. (Adolescents). Alcohol consumption | Sub-local | Family systems theory. (Data from longitudinal survey). Single time point | None | Influences on drinking |
| Stafström et al 2006 113  *A community action programme for reducing harmful drinking behaviour among adolescents: The Trelleborg Project* | To evaluate a 3-year community intervention programme informed by systems thinking by measuring changes in drinking patterns in a 15–16-year-old population. | Sweden. (Adolescents age 15-16).  Alcohol consumption | Local | Systems thinking. (Cross-sectional, questionnaires at several timepoints). 3 years | Community action programme | Impact of intervention |
| Su et al 2018 56  *Influence of parental alcohol dependence symptoms and parenting on adolescent risky drinking and conduct problems: a family systems perspective* | To use a family systems approach to consider spillover and crossover effects of fathers’ and mothers’ alcohol problems and parenting behaviours in relation to adolescents’ risky drinking and conduct problems. | US. (Alcohol dependence parents and adolescents age 12-17). Parental drinking; adolescent risky drinking and conduct | Sub-local | Family systems theory. (Validated clinical questionnaire). Single time point | None | Influences on drinking and related harms |
| Sun 2000 102  *Direct practice with substance abusing mothers in the child welfare system: A system perspective* | To explore the needs and related issues of substance abusing mothers in the welfare system. | Generic. (Substance abusing mothers). Child welfare; guidelines for social workers | Multiple: sub-local and local | Systems perspective. (Non-systematic literature review). Unspecified | None | Practice guidelines |
| Thompson et al 2017 80  *Examining alcohol management practices in community sports clubs: a systems approach* | To investigate the influence of macro-level regulatory systems on alcohol management for community sport organisations. | Australia. (Sporting club administrators and participants). Responsible alcohol management | Multiple: local, regional and national | Systems thinking. (Semi-structured interviews). Single time point | None | Influences on policy |
| Wallack 2006 57  *A community approach to the prevention of alcohol-related problems: The San Francisco experience* | To describe the San Francisco Prevention Project, a community level intervention informed by a systems perspective which is designed to prevent alcohol-related problems. | US. (General population, public health workforce). Street drinking, regulation of outlets, family violence, availability | Local | Systems perspective. (Review of social -epidemiological literature; local data analysis; semi structured interviews and participatory workshops). Unspecified | Community intervention to prevent alcohol-related problems | Programme development and description |
| Wilson et al 2014 85  *The Australian Prevention Partnership Centre: Systems thinking to prevent lifestyle-related chronic illness* | To describe The Australian Prevention Partnership Centre and its approach to chronic-disease prevention using systems thinking. | Australia. (Public health researchers and workforce). Alcohol harm prevention | National | Systems thinking. (Programme description). Single time point | Partnership approach to improve chronic disease outcomes | Programme description |

\*Birckmayer et al 2014 49, Holder et al 2001 108, Holder et al 2001 71, Holder et al 2002 70, Holder et al 2005 111, Holder et al 2010 109

†Gruenewald 2007 103, Gruenewald et al 2014 51

**Table 2: Study characteristics; dynamic simulation modelling**

| Authors and Year  *Title* | Aim | Country. (Population). Alcohol topic | System level(s) | Method. (Model underpinnings). Timeframe | System modifications examined | Types of findings |
| --- | --- | --- | --- | --- | --- | --- |
| Ackleh et al 2009 61 \*  *Ecosystem modeling of college drinking: parameter estimation and comparing models to data* | To present the procedure and results of parameter estimation and to examine the effect of two hypothetical intervention policies. | US. (University students). Consumption; types of drinkers | Multiple: sub-local and local | Continuous, deterministic, dynamical systems compartmental model. (Academic literature; survey data). 10 and 12 years | Reducing environmental wetness; university policies on drinking | Simulated impacts of interventions |
| Apostolopoulos et al 2018 22 †  *Moving alcohol prevention research forward—Part I: introducing a complex systems paradigm* | To outline the limitations of current approaches in alcohol prevention research and to use alcohol misuse in college students to illustrate how a complex systems approach addresses them. | US. (University students). Alcohol misuse | Multiple: sub-local, local, regional and national | Computational modelling methodologies. (Ecosocial; syndemic; and complex systems theories). Unspecified | None | Arguments for paradigm shift and approach |
| Apostolopoulos et al 2018 23 †  *Moving alcohol prevention research forward—Part II: new directions grounded in community-based system dynamics modelling* | To describe computational modelling methodologies, explain the value of community-based system dynamics modelling in alcohol prevention research, and explain how to build alcohol misuse simulation models. | US. (University students). Alcohol misuse | Multiple: sub-local and local | Community-based system dynamics modelling. (Stakeholder workshops; best available data; expert-driven assumptions; historical data; scientific literature). Unspecified | Changing social norms around drinking | Process and illustration of system dynamics modelling |
| Atkinson et al 2017 31 ‡  *Dynamic simulation modelling of policy responses to reduce alcohol-related harms: rationale and procedure for a participatory approach* | To describe the participatory process of developing a dynamic simulation model of possible policy actions to reduce alcohol-related harms in New South Wales. | Australia. (General population). Prevention and treatment of alcohol-related harms (acute and chronic) | Multiple: sub-local and local | Consensus-building in simulation models. (Expert opinion; national and state data; survey data; accepted formulas; theoretical models; systematic reviews; meta-analyses; economic data). Unspecified | 'Lockouts’; retail hours and density restrictions; bans on advertising; minimum pricing; responsible beverage service enforcement | Rationale and procedure for developing a participatory dynamic simulation model |
| Atkinson et al 2018 28 ‡  *Harnessing advances in computer simulation to inform policy and planning to reduce alcohol-related harms* | To develop a decision support tool to test alcohol policy scenarios and to compare estimated impacts over time of a range of trading hour policy options on indicators of acute and chronic alcohol-related harms. | Australia. (General population). Acute and chronic alcohol harms; licensing hours; venue policies | Multiple: Sub-local and local | Agent-based model. (See Atkinson et al 2017 31). 5 years | Changes in venue closing time;  ‘lockouts’ | Development of model; simulated impacts of interventions |
| Atkinson et al 2018 87 ‡  *Impacts of licensed premises trading hour policies on alcohol-related harms* | To use dynamic simulation modelling to compare estimated impacts over time of trading hour policy options on various indicators of acute alcohol-related harm in New South Wales. | Australia. (General population). Acute harms; violence; licensing hours | Multiple: sub-local and local | Agent-based model. (See Atkinson et al 2017 31). 5 years | Changes in venue closing times | Simulated impacts of interventions |
| Castillo-Carniglia et al 2019 42  *Limiting alcohol outlet density to prevent alcohol use and violence: estimating policy interventions through agent-based modelling* | To estimate the association between closing alcohol outlets and alcohol use and alcohol-related violence. | US. (General population). Alcohol consumption; violence; outlet density | Multiple: sub-local and local | Agent-based model. (Census data; state & local data; survey data; ecological niche theory). Unspecified | Capping and reducing outlet density | Simulated impacts of interventions |
| Clapp et al 2018 99 §  *A system dynamic model of drinking events: multi-level ecological approach* | To present an empirically grounded dynamic conceptual model to better understand drinking events. | Generic. (General population). Drinking events; blood alcohol level. | Multiple: sub-local and local | Systems dynamics model. (Academic literature; peer review; field data). 3 hours | None | Conceptual model for future studies |
| Fitzpatrick et al 2012 62 \*  *Forecasting the effect of the Amethyst Initiative on college drinking* | To forecast the effect of the Amethyst Initiative (initiative to reduce the legal drinking age) on college drinking. | USA. (University students). Types of drinker; legal drinking age | Multiple: sub-local and local | Continuous dynamical systems compartmental model. (Academic literature; survey). 10 years | Reducing legal drinking age | Simulated impacts of intervention |
| Fitzpatrick and Martinez 2012 43 ¶  *Agent-based modelling of ecological niche theory and assortative drinking* | To develop a preliminary approach to modelling dynamic properties of the spatial assortment of alcohol outlets. | US. (General population). Characteristics and number of alcohol outlets; drinking habits | Multiple: sub-local and local | Agent-based model. (Theory-led model: Gruenwald 103; local surveys and data). 1 year, 5 years | Varying outlet numbers and attributes | Development of model; simulated impacts of interventions |
| Fitzpatrick et al 2015 64 ¶  *The big impact of small groups on college drinking* | To develop a theoretically-informed agent-based simulation model of a single drinking event to examine college drinking. | US. (University students). Drinking behaviour | Sub-local | Agent-based model. (Theory-led model: social norms; identity control and peer influence). 4 hours | None | Influences on drinking behaviour |
| Fitzpatrick et al 2016 58 ¶  *On the effectiveness of social norms intervention in college drinking: the roles of identity* | To develop an agent-based computational simulation that uses identity control theory and peer influence to model interactions that affect drinking in college students and to simulate the impact of a social norms campaign. | US. (University students). Consumption; heavy episodic drinking | Multiple: sub-local and local | Agent-based model. (Theory-led model: social norms theory, identity control theory, and peer influence). 4 hours | Social norms campaigns | Influences on drinking behaviour; simulated impacts of intervention |
| Freebairn et al 2017 89 ‡  *Knowledge mobilisation for policy development: Implementing systems approaches through participatory dynamic simulation modelling* | To describe the experience of using participatory simulation modelling as a knowledge mobilisation tool in Australian real-world policy settings. | Australia. (General population). Drinking  behaviours; acute and chronic harms | Multiple: sub-local and local | Process of conducting participatory dynamic simulation modelling. (See Atkinson et al 2017 31). Unspecified | Interventions to address alcohol harms | Description, example and argument for approach |
| Freebairn et al 2018 88 ‡  *Decision makers’ experience of participatory dynamic simulation modelling: methods for public health policy* | To report on the experience of end-user decision makers who participated in three participatory simulation modelling for health policy case studies and their perceptions of the value and efficacy of this method. | Australia. (General population). Drinking  behaviours; acute and chronic harms | Multiple: sub-local and local | Semi-structured interviews to understand participatory dynamic simulation modelling. (See Atkinson et al 2017 31). Unspecified | Interventions to address alcohol harms | Views on approach |
| Garrison and Babcock 2009 44  *Alcohol consumption among college students: an agent-based computational simulation* | To develop an agent-based computer model to study how students’ attitudes, their experiences while drinking, and their interactions with others increase or decrease alcohol consumption. | US. (University students). Consumption; influences on drinking | Sub-local | Agent-based model. (Data from student drinking diaries). 8-16 semesters (15 weeks each) | None | Influences on drinking |
| Giabbanelli and Crutzen 2013 119  *An agent-based social network model of binge drinking among Dutch adults* | To use an agent-based social network model to test a number of hypotheses on important aspects of binge drinking in the adult Dutch population. | Netherlands. (Adult general population).  Binge drinking | Sub-local | Agent-based model. (Longitudinal national data; peer selection and peer influence; drinking motives). Unspecified | Intervention to change pressure to drink | Influences on drinking |
| Giraldo et al 2017 59 §  *Modeling and analysis of group dynamics in alcohol-consumption environments* | To construct a system model that characterises how the dynamics of the social interactions, individual characteristics, and environment translate into changes in the drinking patterns of individuals. | US. (General population).  Drinking patterns | Multiple: sub-local and local | System dynamics model. (Theory on group behaviour; field data on drinking). Single drinking event | None | Prediction of drinking patterns |
| Gonzalez Villasanti et al 2020 73 §  *A dynamic multilevel ecological approach to drinking event modelling and intervention* | To provide a system dynamics model to accurately represent a drinking event and provide guidelines for feedback-based behavioural interventions. | US. (General population). Drinking events; blood alcohol content levels. | Multiple: sub-local and local | System dynamics model. (Academic literature, cognitive perspectives, perceptual control theory, experimental data). Single drinking event | Behavioural interventions during drinking events | Development of model; simulated impacts of intervention |
| Gorman et al 2004 100  *Implications of systems dynamic models and control theory for environmental approaches to the prevention of alcohol- and other drug use-related problems* | To set out what a systems-based understanding of alcohol- and drug use-related problems will require and discuss its implications for public policy and prevention programming. | Generic. (General population). Prevention of alcohol misuse | Local | Systems dynamics model. (Complexity and control theory). Unspecified | Possibility of modelling different interventions | Argument for theory and approach |
| Gorman et al 2006 98  *Agent-based modelling of drinking behaviour: a preliminary model and potential applications to theory and practice* | To develop an agent-based simulation model to examine agent–environment interactions that support the development and maintenance of drinking behaviour. | Generic. (General population). Drinking behaviour; drinking states | Multiple: sub-local and local | Agent-based model. (Social influence literature). 1,000 days | Introduction of a new alcohol outlet | Influences on drinking; simulated impact of intervention |
| Hufford et al 2003 65  *Relapse as a nonlinear dynamic system: application to patients with alcohol use disorders* | To use catastrophe theory (subset of nonlinear dynamical systems theory) to describe and predict the relapse process. | US. (Patients with alcohol use disorders). Sub-local | Addiction; alcohol relapse process | Cusp catastrophe model. (Cusp catastrophe theory; primary data). 6 months | None | Model; influences on relapse |
| Jackson et al 2012 104  *Drinking with friends: a cellular automata approach to modeling peer influence on binge drinking behavior* | To use a cellular automata model to simulate the effects of peer influences on binge drinking behaviour to understand alcohol consumption in students. | Generic. (University students). Binge drinking | Sub-local | Cellular automata model. (Academic literature; survey data). 600 (unspecified) time steps | None | Influences on drinking |
| Keyes et al 2019 45  *Assessing the impact of alcohol taxation on rates of violent victimization in a large urban area: an agent-based modelling approach* | To use simulation to estimate the impact of alcohol taxation on drinking, non-fatal violent victimization and homicide in New York City. | US. (General population; heavy drinkers).  Consumption; non-fatal violent victimisation; homicide’ taxation. | Multiple: sub-local and local | Agent-based model. (Census data; cohort studies; national surveys; local surveys; local data). 10 years | Taxation | Simulated impacts of interventions |
| Ip et al 2016 60  *Agent-based modeling of college drinking behavior and mapping of system dynamics of alcohol reduction using both environmental and individual-based intervention strategies* | To describe an agent-based model that explores the dynamic of college drinking and the use of system dynamic modelling to explore the causal relationship between personal / environmental factors and alcohol consumption. | US. (University students). Consumption | Multiple: sub-local, local and regional | Agent-based model and use pf system dynamics modelling. (Adapted ABM from Gorman et al 2006 98; national survey). 240 months | Marketing of alcohol; availability of alcohol; university culture around alcohol | Influences on drinking |
| Lamy et al 2011 77  *An agent-based model of alcohol use and abuse: SimARC* | To create a social simulation, which integrates three levels of analysis (micro, meso, macro) in order to get a better understanding of alcohol use and misuse. | Australia. (General population). Consumption; taxation | Multiple: sub-local and local | Agent-based model and causal loop diagrams. (Theory that alcohol-related harms caused by interactions across system levels). 1 year | Taxation | Impacts of simulated interventions |
| Mubayi et al 2010 68 #  *Impact of relative residence times in highly distinct environments on the distribution of heavy drinkers* | To estimate the effects of social influence, social context, and residence time on the initiation and maintenance of moderate and heavy drinking. | US. (University students). Drinking behaviour; types of drinkers; alcohol environment | Multiple: sub-local and local | Deterministic compartmental  Model. (National and regional data). 6 years | None | Development of model; influences on drinking |
| Mubayi et al 2011 66 #  *Types of drinkers and drinking settings: an application of a mathematical model* | To use US college drinking data and a simple population model of alcohol consumption to explore the impact of social and contextual parameters on the distribution of light, moderate and heavy drinkers. | US. (University students). Drinking behaviour; types of drinkers; alcohol environments | Multiple: sub-local and local | Deterministic compartmental  Model. (National and regional data). 4 years | None | Development of model; influences on drinking |
| Mubayi and Greenwood 2013 67 #  *Contextual interventions for controlling alcohol drinking* | To understand the influence of environment-specific multiple control programs  involving interventions in distinct college environments. | US. (University students). Types of drinkers | Multiple: sub-local and local | Deterministic and stochastic compartmental models. (National and regional data). 1 and 1.25 years | ‘Intervention rates’ in low and high-risk drinking environments | Simulated impact of interventions |
| O’Donnell et al 2017 90 ‡  *Participatory simulation modelling to inform public health policy and practice: rethinking the evidence hierarchies* | To describe the benefits of dynamic simulation modelling and its unique approach to evidence synthesis, through the example of alcohol-related chronic disease and acute harms prevention. | Australia. (General population). Drinking  behaviours; acute and chronic harms | Multiple: sub-local and local | Description of participatory simulation modelling as an evidence synthesis tool. (See Atkinson et al 2017 31). Unspecified | None | Argument for approach |
| Ormerod and Wiltshire 2009 96  *Binge drinking in the UK: A social network phenomenon* | To examine the extent to which the sudden emergence of the binge drinking problem in the UK can be explained as a social network phenomenon. | UK. (Young adults age 18-24). Binge drinking | Sub-local | Agent-based model. (Primary data collection (survey); social network theory). Unspecified | None | Influences on drinking |
| Perez et al 2012 81  *SimAmph: An agent-based simulation model for exploring the use of psychostimulants and related harm amongst young Australians* | To describe SimAmph, an agent-based simulation model which simulates patterns of drug use and related harm amongst young Australians. | Australia. (Young adults). Alcohol and drug use | Multiple: sub-local and local | Agent-based model. (Primary research; academic literature; national survey; economic data; social engagement theories). 200 weeks | None | Influences on drinking and drug use |
| Probst et al 2020 74 \*\*  *The normative underpinnings of population-level alcohol use: an individual-level simulation model* | To test the ability of social norm mechanisms to predict changes in population-level drinking patterns. | US. (General population). Drinking patterns | Multiple: sub-local, local, national | Agent-based model. (Social norms theory; survey data). 20 years | Normative interventions: decrease perception bias, reduce desire to drink, public campaign | Development of conceptual model; mechanisms of drinking patterns; simulated impacts of interventions |
| Purshouse et al 2014 92  *Evolutionary parameter estimation for a theory of planned behaviour microsimulation of alcohol consumption dynamics in an English birth cohort 2003 to 2010* | To present a theory-driven model that can reproduce alcohol consumption dynamics observed in a population over time. | UK. (Young adults age 18-24). Alcohol consumption | Sub-local | Agent-based model. (Theory-driven model: theory of planned behaviour; national surveys). 8 years | None | Influences and predictors of drinking |
| Rasul et al 2011 63 \*  *Heavy episodic drinking on college campuses: does changing the legal drinking age make a difference?* | To extend Schribner et a’s 2009 compartmental model to evaluate the consequences of lowering the legal drinking age. | US. (University students). Legal drinking age; types of drinkers | Multiple: sub-local and local | Continuous, deterministic, dynamical systems compartmental  model. (Academic literature; survey data). Unspecified | Lowering the legal drinking age | Simulated impact of intervention |
| Redfern et al 2013 97  *An open-data, agent-based model of alcohol related crime* | To create an agent-based simulation model of alcohol-related violent crime to predict areas of likely violent crime. | UK. (General population). Violence | Multiple: sub-local and local | Agent-based model. (Academic literature; geographical and crime data). 10 hours | None | Predictions of alcohol-associated harms |
| Salmon et al 2020 91  *Computational modelling and systems ergonomics: a system dynamics model of drink driving-related trauma prevention* | To develop a system dynamics model that simulates the behaviour of a drink driving-related trauma system and explore the potential impact of different road safety policy interventions. | Australia. (General population). Drink driving | Multiple: sub-local, local, regional, national | System dynamics model. (Academic literature, public data on road crashes; subject expert consultation). 30 years. | Road safety policy; population-level public health interventions to reduce prevalence of alcohol misuse | Development of model; simulated impacts of interventions |
| Scribner et al 2009 48 \*  *A systems approach to college drinking: Development of a deterministic model for testing alcohol control policies* | To use a systems approach to understand the dynamics of student drinking behaviour and thus forecast the impact of campus policy to address the problem. | US. (University students). Consumption; types of drinkers | Multiple: sub-local and local | Continuous, deterministic, dynamical systems compartmental  model. (Academic literature; survey data). 20 years | University policies on drinking | Development of model; drinking styles; simulated impacts of interventions |
| Schuhmacher et al 2014 107  *Using an agent-based model to simulate the development of risk behaviors during adolescence* | To build an agent model to understand how friendship groups evolve, the role of behavioural similarity in friendship formation and how homogeneity among peers emerges. | Generic. (Adolescents).  Adolescent consumption | Sub-local | Agent-based model. (Theories and literature on adolescent engagement in risky behaviours). 200 days | None | Model for future use; simulated trajectory of adolescent alcohol use |
| Scott et al 2016 78 ††  *SimDrink: an agent-based NetLogo model of young, heavy drinkers for conducting alcohol policy experiments* | To show a proof-of-concept agent-based model ‘SimDrink’, built in NetLogo, which simulates a population of young heavy drinkers on a night out in Melbourne to inform policy decisions. | Australia. (Young adults age 18-25) heavy drinkers). Consumption; intoxication; aggression; venue  policies | Multiple: sub-local and local | Agent-based model. (Academic literature and fieldwork; city- and population-specific study; local data). One night | Public transport, ‘lockouts;’  enforcement; outlet closing times; drink prices | Simulated impacts of interventions |
| Scott et al 2016 84 ††  *The effects of extended public transport operating hours and venue lockout policies on drinking-related harms in Melbourne, Australia: Results from SimDrink, an agent-based simulation model.* | To test the effects of improved public transport and venue lockouts on a range of alcohol-related harms among a population of young adults engaging in heavy drinking in Melbourne. | Australia. (Young adults age 18-25, heavy drinkers). Aggression; venue ejections; consumption; transport harms; venue policies; transport policies | Multiple: sub-local and local | Agent-based model. (Academic literature and fieldwork; city- and population-specific study; local data). Night out starting at 5 pm | Changes to public transport hours; ‘lockouts’ | Simulated impacts of interventions |
| Scott et al 2017 83 ††  *Using simulation modelling to examine the impact of venue lockout and last-drink* *policies on drinking-related harms and costs to licensees* | To estimate the public health gains and licensee costs of venue lockout and last-drink policies in a population of young adults engaging in heavy drinking. | Australia. (Young adults age 18-25) heavy drinkers). Aggression; consumption; retailers’ revenue | Multiple: sub-local and local | Agent-based model. (Academic literature and fieldwork; city- and population-specific study; local data). Saturday night starting at 5 pm | ‘Lockouts;’ last-drink policies | Simulated impacts of interventions |
| Spicer et al 2012 116  *Bars on blocks: a cellular automata model of crime and liquor licensed establishment density* | To illustrate a cellular automata model which simulates how densities of licenced premises may affect violent offending within an entertainment district in Vancouver, British Columbia. | Canada. (General population). Violence and disorder; outlet density | Local | Cellular automata model. (Theoretical literature; local data). 2,000 days | Groupings of licenced venues | Simulated impacts of interventions |
| Stankov et al 2019 46  *Depression and alcohol misuse among older adults: exploring mechanisms and policy impacts using agent-based modelling* | To explore how multi-level factors impact the prevalence of depression and alcohol misuse among urban older adults and to simulate the impact of alcohol taxation policies and interventions that increase social connectedness. | US. (Older urban adults age 65+; older heavy drinkers age 65+). Depression; alcohol misuse | Multiple: sub-local and local | Agent-based model. (Data from longitudinal cohort study and environmental data; academic literature). 5 years | Social connection interventions; taxation | Simulated impacts of interventions |
| Tawileh et al 2008 26  *A system dynamics approach to assessing policies to tackle alcohol misuse* | To describe the development of an influence diagram for alcohol misuse and to demonstrate the utility of this approach through a simulation model. | UK. (General population). Consumption; binge drinking | Multiple: local and national | System dynamics model. (Validated with government statistics and quantitative data). 27 years | Alcohol taxation policy; licensing restrictions; bar and pub opening hours; awareness campaigns | Illustration of approach; simulated impacts of interventions |
| Vu et al 2020 76 \*\*  *A software architecture for mechanism-based social systems modelling in agent-based simulation models* | To develop a mechanism-based social systems model and to demonstrate how to populate the model by showing the development of a simulation of a single mechanism-based theory that aims to explain long term changes in population alcohol use. | US. (General population). Alcohol consumption patterns. | Multiple: sub-local, local, national | Agent-based model. (Social norms theory; social roles theory; survey and census data). 20 years | None | Development of model; argument for approach; explanation of dynamics of alcohol use patterns |
| Vu et al 2020 75 \*\*  *Multiobjective genetic programming can improve the explanatory capabilities of mechanism-based models of social systems* | To propose and demonstrate a new model discovery framework using a complex systems modelling case study of change and stasis in societal alcohol use patterns in the US over the period 1980–2010. | US. (General population). Alcohol consumption patterns. | Multiple: sub-local, local, national | Agent-based model. (Social role theory; survey and census data). 30 years. | None | Development of model; argument for approach; mechanisms which drive alcohol use |

\*Ackleh et al 2009 61, Fitzpatrick et al 2012 62, Rasul et al 2011 63, Scribner et al 2009 48

†Apostolopoulos et al 2018 22, Apostolopoulos et al 2018 23

‡Atkinson et al 2017 31, Atkinson et al 2018 28, Atkinson et al 2018 87, Freebairn et al 2017 89, Freebairn et al 2018 88, O’Donnell et al 2017 90

§Clapp et al 2018 99, Giraldo et al 2017 59, Gonzalez Villasanti et al 2020 73

¶Fitzpatrick and Martinez 2012 43, Fitzpatrick et al 2015 64, Fitzpatrick et al 2016 58

#Mubayi et al 2010 68, Mubayi et al 2011 66, Mubayi and Greenwood 2013 67

\*\*Probst et al 2020 10, Vu et al 2020 76, Vu et al 2020 75

††Scott et al 201678, Scott et al 2016 84, Scott et al 2017 83

**Table 3: Main theories in theory-led approaches**

| Theory | Description | Application of theory in alcohol-harm prevention research |
| --- | --- | --- |
| Systems theory | A system is made up of interconnected elements bounded in some way within a broader context. Systems theory emphasises the relationships between elements and understanding how different parts of the system interact and influence one another 36,128. | Argument for systems-thinking lens in prevention and treatment efforts 71,108,109.  Development of specific systems-informed approaches to interventions and programmes 57,71,85,113,117.  Systems approach to drug and alcohol workforce development 106 and practitioner guidelines 102.  Systems theory used to inform analytical framework 80,112,117,118. |
| Complex adaptive systems and complexity theory | A complex adaptive system (CAS) is made up of elements who interact with each other over time, without a central organising authority, to generate behaviour at the system level that cannot be reduced to the actions of individual actors. Relationships within a CAS are non-linear and may be unpredictable, as elements and the system adapt and co-evolve in response to internal and external stimuli; responses within the system may amplify or dampen system changes, depending on the system’s capacity to absorb or respond to change 129-132. Complexity theory is “the interdisciplinary understanding of reality as composed of complex open systems with emergent properties and transformational potential” 133 p.97. | Argument for use of complex systems lens in alcohol-harm prevention research and practice 24,70 and development of a complex systems model of alcohol use and associated harms 49.  Complex adaptive systems used as an analytical lens, drawing on theory to visualise the system structure, represent causal pathways and feedback loops and identify possible intervention points 29,93,121.  Use of complexity theory to inform sampling strategy, data collection methods and/or analysis 79,82,86,95. |
| Ecological systems theories | Ecological systems theories emphasises the wider influences – operating at different systemic levels - on an individual’s behaviour and their health 134. Within alcohol harm prevention research, used to understand the contexts that influence drinking and associated harms 51,103. | Theoretical lens used to situate and understand influences on young people’s drinking behaviour in college students 50, South African female adolescents 115, Asian American 72, South Korean 120, Mexican American 69 and American adolescents 54.  Theoretical lens to develop a behavioural ecological model for alcohol consumption 49 and developmental ecological model of alcoholism 110.  Theoretical framework to inform social workers’ development 94. |
| Niche theory  Assortative drinking | Niche theory explains how specialist markets emerge; consumers have different types of demands and in response, the market diversifies and segments, creating niche markets for different consumer bases 103.  Assortative drinking highlights the phenomena that individuals tend to drink with people similar to themselves and visit establishments with cliental that resemble them 103. | Niche theory and the concept of assortative drinking used to explain and make sense of the association between environmental characteristics and alcohol consumption and related harms in a social-ecological model 51,103. |
| Family systems theory | Families are viewed as a system and the theory gives special consideration to how the individual family members interact and relate to each other with a key assumption that family members are interdependent and influence each other 135,136. | To explore adolescent alcohol use in the context of their parents’ substance misuse 56 or in relation to family cohesion and emption distress 55.  To make sense of substance misuse by parents and its effect on the family’s general well-being 114.  To create a theoretical mode of adolescent alcohol use and test it using empirical data 52.  Along with attachment theory, to generate predictor variables in order to understand differences in alcohol addiction amongst American Indian adoptees compares to white adoptees 53. |
| Theories of practice | Emphasises the shared group practices in which people engage. These practices are embedded in daily life and are generally stable. In order to create change within the system, normal routines need to be disrupted 105,137. | Argument for the use of the theories of practice to better understand alcohol consumption trends and design more effective interventions, moving away from theories of individual behaviour change. 105. |
| Information theory | Information theory is used to understand how much and in what ways information is stored and communicated. A key concept is entropy 47,138. | To explore how alcohol regulations and driving laws in one state influence neighbouring states in the United States 47. |

**Table 4: Study characteristics; social network systematic reviews**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Study | Aim | Search dates | Countries. (Population). Alcohol topic | System level(s) | Method. (Data sources) | System modifications examined | Types of findings |
| Henneberger et al 2020 39  *Peer influence and adolescent substance use: a systematic review of dynamic social network research* | To systematically review the extent to which the emerging body of empirical research applying stochastic actor-based models supports the association between peer selection and socialization and adolescent substance use. | No restriction | US, Italy Finland, Netherlands, UK. (Adolescents; 10-18). Alcohol use, tobacco use, drug use. | Sub-local | Stochastic actor-based models. (Longitudinal survey data) | None | Association between peer selection and socialisation and adolescent alcohol use |
| Knox et al 2019 40  *Using social network analysis to examine alcohol use among adults: A systematic review* | To review empirical studies that used social network analysis to assess the influence of social network characteristics on drinking behaviours in adults. | Up to March 2019 | US, Germany, Belgium, Netherlands, South Africa (Adults, majority young adults and university students). Alcohol consumption | Sub-local | Social network analyses. (Cross sectional and longitudinal survey data) | None | Association of social network characteristics with alcohol consumption |
| Montgomery et al 2020 38  *Peer social network processes and adolescent health behaviors: a systematic review* | To review studies that investigated the association between peer network processes and health behaviours in adolescents, particularly in relation to the extent to which specific network processes were observed across common adolescent health behaviours. | Up to October 2018 | US, Italy, Finland, Taiwan, Indonesia. (Adolescents; 13-18) Adolescent drinking and adolescent drinking and smoking | Sub-local | Social network analyses. (Cross sectional and longitudinal survey data) | None | Social network predictors of drinking and drinking and smoking behaviours in adolescents |

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