Final Application

There is a well-established association between psychological disorders and substance abuse, with very high reported comorbidity rates. Unraveling causality in this complex problem is hugely challenging: the propensity for addiction is higher in individuals with mental health issues, and seemingly people abusing illicit substances are more likely to develop mental health issues. This complexity stems from the realization that addiction and mental health problems are driven by underlying psychological (e.g., mental unrest) and social (e.g., peer pressure) processes. While significant progress has been made through a complexity approach to psychology, societal environments and social components are often modeled in simplistic ways, typically as mere covariates. Increasing urbanization places the individual in ever increasingly complex social and environmental contexts that can no longer be ignored. Psychosocial factors, such as: peer pressure, (lack of) social support, and availability of substances, play a vital a role in the use of addictive substances. In addition, people shape and influence their social environment as much as they are shaped by it – clearly the mental state of individuals will impact the way they deal with their social environment.

In this proposal we plan to develop novel computational models to study the dynamics of addictive substance (ab)use. Our central hypothesis is that the complex dynamics of addiction and mental health issues are driven by psychological and social dynamics and we aim to build complex system models to understand this. The goal of this project is to integrate the psychological and social levels of explanation in an encompassing computational modeling framework. This modeling framework will be applied to study the interplay of substance use and mental health, and will provide a toolbox applicable to study other common mental health conditions throughout the Urban Mental Health (UMH) research priority area.

Scientific Background and Approach:

Complex systems thinking has become a popular way to better understand human behavior and mental health. In particular, the *network perspective of psychology* conceptualizes behavior, affect, and cognition as emergent phenomena, from a complex interaction of psychological and biological components. Several methodological innovations allow for mapping out such interactions from data, leading to several applications in, for example, the study of depression, substance usage, and psychosis.[1] While this surge of work has led to revolutionary new insights in these diverse fields of study, the use of exploratory statistical analysis of data to derive network models has several drawbacks: most models feature linear dynamics trained on past data, and will therefore perform poorly in predicting vast future changes, such as phase transitions and the effect of interventions, and any estimation technique (both cross-sectional and longitudinal studies) assumes independence between people, and does not take *social interactions* into account.

Cross-disciplinary collaborative efforts, partly facilitated by the Institute for Advanced Studies (IAS), have recently led to computational theoretical models to study, e.g., the usage of addictive substances, attitude formation, panic disorder, and avoidance behavior.[2] Fig. 1 shows a simplified version of a model for avoidance behavior, which models a person that takes regular large doses of benzodiazepine to reduce anxiety. These drugs may reduce anxiety momentarily, but also bring side effects such as increased

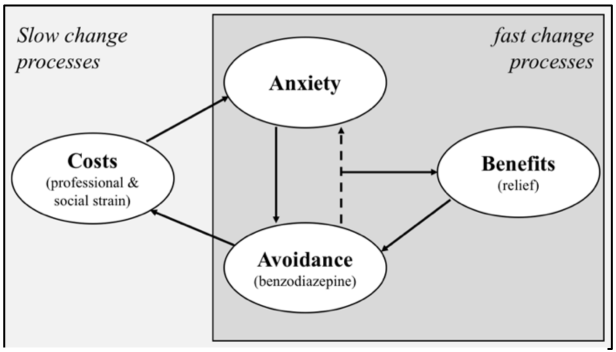

Figure 1. A simplified version of a newly proposed computational model for avoidance behavior. In this model, increased anxiety leads to the use of benzodiazepine as avoidance behavior, which provides short term benefits (reduced anxiety), but long-term costs and increased anxiety due to professional and social strains caused by the use of benzodiazepine.

[1] See DOI:10.1007/s00127-016-1319-z for a relatively recent literature review.
[2] This model was developed in an IAS master thesis by Julian Burger. An updated version of this work is under review at *BMC Medicine* (https://psyarxiv.com/gw2uc/).

drowsiness and impulsivity, which may lead to professional and social strain, increasing anxiety in the long run.

Computational models, such as the one shown in Fig. 1, differ from conceptual models in that each relationship is defined mathematically—often categorized by non-linear relations—and therefore new data can be generated from the theoretical model. Such a model may be used to evaluate the effect of different treatment outcomes (e.g., behavioral treatment targeting drug use or cognitive treatment targeting anxiety). However, this model does not consider the immediate social environment (Fig. 2). For example, if this person is surrounded with peers that use addictive substances, increasing both acceptability and availability of drug usage, then a behavioral intervention that removes availability of benzodiazepine may well lead to harmful outcome in which the person replaces this with an even more harmful substance.

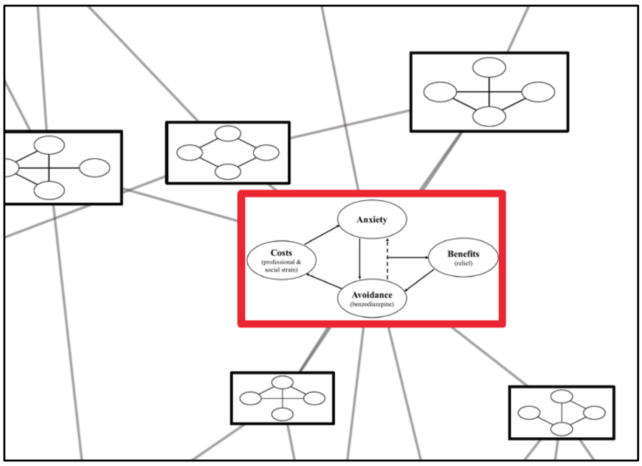

Figure 2. To further understand the motives and behavior of people regularly (ab)using addictive substances, we need to consider not only their psychological dynamics, but also their social environment in which someone interacts with other people that are also driven by psychological dynamics.

Categorizing within-person dynamics together with computational models for social dynamics is a novel direction of research that is required to fully gasp the complexity of human behavior. We plan to develop stylized models based on the complex agent network framework[3] and models of opinion dynamics to investigate the social dynamics (and social networks) of addiction. An example of recent work on this is a computational model for polarization, which combines Ising model dynamics for attitude formation together with agent-based modeling to present theoretical explanations of polarization in modern urban societies.[4] In this work, each node in the social network is an agent that is modeled, in turn, through the use of an Ising model to form an internal *attitude network*, which may lead to complex behavior in the form of phase transitions in opinions. By including social dynamics, the model makes stronger predictions on which interventions (social or psychological) would be most successful when aiming to try to change a person's opinion. While this work may serve as an example to the proposed project, a computational model for addictive substance use will need to be more extensive, requiring at least three stable states (abstinence, recreational use and abuse).

Main Objective, Specific Aims:

This project uniquely will combine advances in computational modeling of psychological dynamics and social dynamics (micro and meso level). This will be facilitated by combining the expertise of the two applicants: Sacha Epskamp, an expert on psychological network modeling, and Michael Lees, an expert on social network analysis and agent-based modeling. The project will be subdivided in four subprojects:

Subproject I: An encompassing framework for integrating such different levels of explanation. The first project will be a methodological project, aimed at constructing a framework in which computational models that integrate psychological and social dynamics can be formed. The goal of this subproject is to provide a toolset that can be used in the remainder of the current project, as well as by other researchers of the Urban Mental Health research priority area (UMH). The expected output of this subproject is a flexible software suite and a tutorial paper explaining how the software can be used.

Subproject II-A: A comprehensive computational model of addictive substance use in dense populations. In subproject II, we will apply the methods developed in subproject I to form, for the first

[3] For example: DOI:10.1016/j.asoc.2015.08.010.

[4] Based on a manuscript by Van der Maas, Dalege, & Waldorp. For more information on attitude networks, see DOI:10.1080/1047840X.2018.1537246.

time, a comprehensive model for addictive substance use in dense populations. The model will consider within-person dynamics, such as craving of substances, as well as social interactions that play a role in the spread of certain substances. Furthermore, the model should make clear predictions on what interventions are most effective in managing addiction spread. These interventions may be both psychological or social.

Subproject II-B: Model analysis using large available empirical datasets. When suitable theoretical predictions are derived from this computational model, we will aim to test the model using large datasets that are already available. This data can be applied for, or may be gathered. For example, a computational model for addictive substance use should consider that substance use spreads differently in certain societies compared to others, as well as how people progress in substance use over their life. We already have access to large panel datasets of substance use and mental health variables measured on several repeated waves in the SHARE dataset (http://www.share-project.org/), LISS dataset (https://www.lissdata.nl/), and several datasets through our collaboration with Virginia Commonwealth University (https://vipbg.vcu.edu/research/datasets-projects/).

Subproject III: A roadmap for future research. While subproject II-B aims to support the model using existing datasets, we also recognize that ideal data for studying complex interplays between psychological and social dynamics may not yet exist. In particular, many psychological studies do not take social structure into account, and assume that each individual is independent from all other individuals in the sample. The last project will focus on proposing new methods for gathering data or explore merging existing datasets such that the proposed models may better be validated. Conceptual models are often an ideal way to guide future data collection and the hope is that through the understanding we develop from our novel modeling approach we will develop guidelines for future data collection and this in turn will lead to future UMH research projects.

UMH collaboration: transfer to common mental health conditions. As this project is financed by the UMH, which aims to tackle common mental health conditions from diverse multi-disciplinary angles, a large part of this project will be reserved fully for collaborative work. The goal of these collaborations is to supply researchers with the tools necessary to study topics of interest while taking the full complexity of psychological and social dynamics into account. To this end, the project may make a vital contribution to ongoing IAS/UMH projects. The exact collaborations will depend on the proposals that are accepted

One expected intensive collaboration will be with the ongoing large IAS project on the complexity of depression research, currently lead by Prof. Bockting, Prof. Borsboom and Prof. Sloot, In that project, qualitative interviews with experts from many fields of study have identified a large number of factors that play a role in the onset and maintenance of depression. In addition to psychological factors (e.g., cognitions, stress, self-regulation), recurring factors of importance were social factors such as the role of the family in upbringing, peers for social support, and the (loss of) relationship with a spouse. The developed toolbox in the proposed research project may play a vital part in modeling the interaction between such psychological and social factors in forming a computational model for depression.