Simulation of a 'suicidal mind': Using the Integrated Motivational Volitional model of suicide to demonstrate dynamic suicidal states.

Gabe McDonnell Maayan
Boston University and
Center for Mind and Culture
566 Commonwealth Ave, Boston, MA 02215
(314) 503-6760
gmaayan@bu.edu

Andrew Page
Western Sydney University

Elizabeth Conroy
Western Sydney University

Rory C O'Connor
University of Glasgow

Greg Carter
The University of Newcastle Australia

Wesley J Wildman
Boston University and
Center for Mind and Culture
wwildman@bu.edu

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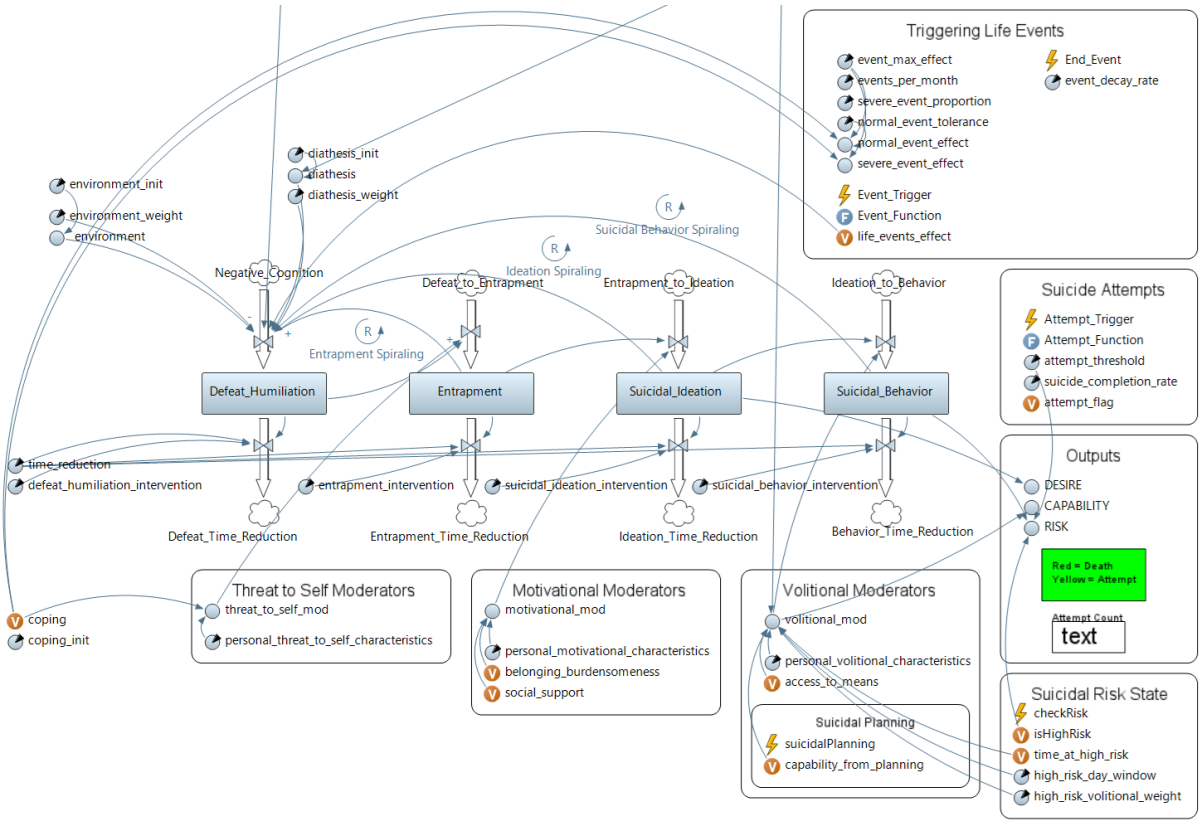
Suicide remains an important global public health priority, with over 720,000 deaths by suicide globally per year, two-thirds of deaths occurring in low- and middle-income countries. (World Health Organization, 2025) Suicide is the third leading causes of death among young people (15-29 years), and intentional self-harm is of a similar magnitude to global rates in traffic injury. (Global Burden of Disease Collaborative Network, 2024) Suicidal behaviors are characterized by a complex, multi-factorial etiology, with interacting social, cultural, biological, psychological, and environmental determinants that can affect individuals across the life-course. (World Health Organization, 2025)

Dynamic simulation models (DSMs) are computational representations of the real world that aim to capture the dynamics and behavior of a whole system or population, (El-Sayed and Galea, 2017) and are methods that can explicitly capture the complex behavior of suicide. Computational simulation has a long history in disciplines such as ecology, physics, and engineering. In population health, DSMs have mainly been used for infectious diseases - and became even more prominent in guiding responses to the recent COVID-19 pandemic. DSM's are increasingly recognized for their broader value in helping to solve complex problems for other population health outcomes. (Galea, Riddle and Kaplan, 2010)

Previous uses of computational simulation in suicide prevention have largely considered aggregate patterns of suicidal behavior in populations. However, there is also scope to use DSMs to describe and understand individual behaviors, to operationalize and potentially validate specific psychological theories that attempt to incorporate the range of complex determinants of suicidal behavior and articulate why some individuals might engage in suicidal behavior, whereas others do not. This study uses three synthesized theories to develop a DSM. The first is the Integrated Motivational-Volitional (IMV) Model of suicide, a 'tri-partite' model that describes the biopsychosocial context in which suicidal ideation and behavior may emerge, factors that determine the emergence of suicidal ideation, and factors that determine the transition from ideation to behavior. (O'Connor and Kirtley, 2018) We also draw on the Fluid Vulnerability Model (Rudd, 2006) which conceptualizes suicidal behavior as inherently dynamic and non-linear, and which has been extended by Bryan et al., by incorporating the Cusp-Catastrophe model form dynamical systems theory to capture nonlinear change processes and sudden shifts that are observed of suicidal behavior. (Bryan *et al.*, 2020) Bryan et al.'s work also describes characteristic scenarios of suicidal behavior that we use to validate the behavior of our model.



Our DSM (pictured above) is a system-dynamics model of 'suicidality' in an individual. It simulates how the levels of defeat/humiliation, entrapment, suicidal ideation, and suicidal behavior, the key elements of the IMV model, change over time. Because data for time-varying estimates of these elements is extremely sparse, the units of values produced by the model are abstract and cannot be understood to have a direct relation to a real-world metric. Future work will include calibrating the model using ecological momentary assessment data (for example Kleiman *et al.*, 2017; Bentley *et al.*, 2021) to tie the values to data. However, we can still create generic scenarios and observe the resulting simulation behavior to validate the model.

Our validation consists of expert analysis of model outcomes when varying parameters of interest, as well as through recreating characteristic scenarios of suicidal behavior. Expert analysis of 4.2 million simulations determined that model's behavior in response to varying parameters of interest was consistent with expectations. The model could also recreate the 'stable,' 'dysregulated,' and 'discontinuous' nonlinear pathways proposed in Bryan et al.'s research supporting the validity of the DSM and its underlying theoretical synthesis.

We also tested the effect of exposing the simulated individual to a simplified and idealized health service system. We found that health service access resulted in stabilization of suicidal ideation and behavior over time, but the effect varied by frequency of contact. Future work will include additional and more realistic intervention testing, both at the health services level and at the individual treatment level.

This model demonstrates that DSMs can quantify and refine theories of suicidal behavior. This suggests potential for using DSMs in virtual case studies to assist clinical decision making and training, or to investigate interventions. Suicide prevention research studies are often costly and pose a risk to trial participants. Completing tests in-silico is fast, cheap, and can direct researchers down the safest and most promising path before attempting real-world trials.

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