Models in social psychology and agent-based social simulation

Review of Artificial Societies and Social Simulation

Models in Social Psychology and Agent-Based Social simulation – an interdisciplinary conversation on similarities and differences

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Introduction

Understanding how individual or group behaviour are influenced by the presence of others is something both social psychology and agent-based social simulation are concerned with. However, there is only limited overlap between these two research communities, which becomes clear when terms such as "variable", "prediction", or "model" come into play, and we build on their different meanings. This situation challenges us when working together, since it complicates the uptake of relevant work from each community and thus hampers the potential impact that we could have when joining forces.

We[1] – a group of social psychologists and social simulation modellers – sought to clarify the meaning of models and modelling from an interdisciplinary perspective involving these two communities. This occurred while starting our collaboration to formalise 'social identity approaches' (SIA). It was part of our journey to learn how to communicate and understand each other's work, insights, and arguments during our discussions.

We present a summary of our reflections on what we learned from and with each other in this paper, which we intend to be part of a conversation, complementary to existing readings on ABM and social psychology (e.g., Lorenz, Neumann, & Schröder, 2021; Smaldino, 2020; Smith & Conrey, 2007). Complementary, because one comes to understand things differently when engaging directly in conversation with people from other communities, and we hope to extend this from our network to the wider social simulation community.

What are variable- and agent-based models?

We started the discussion by describing to each other what we mean when we talk about "a model" and distinguishing between models in the two communities as variable-based models in social psychology and agent-based modelling in social simulation.

Models in social psychology generally come in two interrelated variants. Theoretical models, usually stated verbally and typically visualised with box-and-arrow diagrams as in Figure 1 (left), reflect assumptions of causal (but also correlational) relations between a limited number of variables. Statistical models are often based in theory and fitted to empirical data to test how well the explanatory variables predict the dependent variables, following the causal assumptions of the corresponding theoretical model. We therefore refer to social-psychological models as *variable-based models* (VBM). Core concepts are *prediction* and *effect size*. A prediction formulates whether one variable or combination of more variables causes an effect on an outcome variable. The effect size is the result of testing a prediction by indicating the strength of that effect, usually in statistical terms, the magnitude of variance explained by a statistical model.

It is good to realise that many social psychologists strive for a methodological gold standard using controlled behavioural experiments. Ideally, one predicts data patterns based on a theoretical model, which is then tested with data. However, observations of the real world are often messier. Inductive post hoc explanations emerge when empirical findings are unexpected or inconclusive. The discovery that much experimental work is not replicable has led to substantial efforts to increase the rigour of the methods, e.g., through the preregistration of experiments (Eberlen, Scholz & Gagliolo, 2017).

Models in Social Simulation come in different forms – agent-based models, mathematical models, microsimulations, system dynamic models etc – however here we focus on agent-based modelling as it is the dominant modelling approach within our SIAM network. Agent-based models reflect heterogeneous and autonomous entities (agents) that interact with each other and their environments over

time (Conte & Paolucci, 2014; Gilbert & Troitzsch, 2005). Relationships between variables in ABMs need to be stated formally (equations or logical statements) in order to implement theoretical/empirical assumptions in a way that is understandable by a computer. An agent-based model can reflect assumptions about causal relations between as many variables as the modeller (team) intends to represent. Agent-based models are often used to help understand[2] *why* and *how* observed (macro) patterns arise by investigating the (micro/meso) processes underlying them (see Fig 1, right).

The extent to which social simulation models relate to data ranges from 'no data used whatsoever' to 'fitting every variable value' to empirical data. Put differently, the way one uses data does not define the approach. Note that assumptions based on theory and/or empirical observations do not suffice but require additional assumptions to make the model run.

(https://roasss.files.wordpress.com/2022/09/picture-1.png)
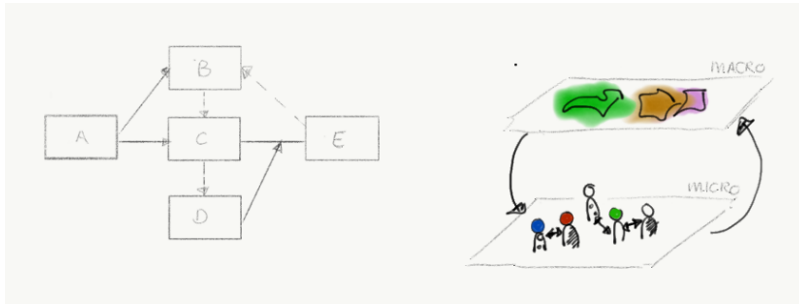
Fig. 1: Visualisation of what a variable-based model in social psychology is (left) and what an agent-based model in social simulation is (right).

Comparing models

The discussion then moved from describing the meaning of "a model" to comparing similarities and differences between the concepts and approaches, but also what seems similar but is not…

Similar. The core commonalities of models in social psychology (VBM) and agent-based social simulation (ABM) are 1) the use of models to specify, test and/or explore (causal) relations between variables and 2) the ability to perform systematic experiments, surveys, or observations for testing the model against the real world. This means that words like 'experimental design', 'dependent, independent and control variables' have the same meaning. At the same time some aspects that are similar are labelled differently. For instance, the *effect size* in VBMs reflects the magnitude of the effect one can observe. In ABMs the analogy would be the sensitivity analysis, where one tests for the importance or role of certain variables on the emerging patterns in the simulation outcomes.

False Friends. There are several concepts that are given similar labels, but have different meanings. These are particularly important to be aware of in interdisciplinary settings as they can present "false friends". The false friends we unpacked in our conversations are the following:

- **Model:** whether the model is variable-based in social psychology (VBM) or agent-based in social simulation (ABM). The VBM focuses on the relation between two or a few variables typically in one snapshot of time, whereas the ABM focuses on the causal relations (mechanisms/processes) between (entities (agents) containing a number of) variables and simulates the resulting interactions over time.
- **Prediction**: in VBMs a prediction is a variable-level claim, stating the expected magnitude of a relation between two or few variables. In ABMs prediction would instead be a claim about the future real-world system-level developments on the basis of observed phenomena in the simulation outcomes. In case such prediction is not the model purpose (which is likely), each future simulated system state is sometimes labelled nevertheless as a prediction, though it doesn't mean to be necessarily accurate as a prediction to the real-world future. Instead, it can for example be a full explanation of the mechanisms required to replicate the particular phenomenon or a possible trajectory of which reality is just one.
- **Variable**: here both types of models have variables (a label of some 'thing' that can have a certain 'value'). In ABMs there can be many variables, some that have the same function as the variables in VBM (i.e., denoting a core concept and its value). Additionally, ABMs also have (many) variables to make things work.
- **Effect size:** in VBM the magnitude of how much the independent variable can explain a dependent variable. In ABM the analogy would be sensitivity analysis, to determine the extent to which simulation outcomes are sensitive to changes in input settings. Note that, while effect size is critical in VBMs, in ABMs small effect sizes in micro interactions can lead toward large effects on the macro level.
- **Testing:** VBMs usually test models using some form of hypothesis testing, whereas ABMs can be tested in very different ways (see David et al (2019)), depending on the purpose they have (e.g., explanation, theoretical exposition, prediction, see Edmonds et al. (2019)), and on different levels. For instance, testing can relate to the verification of the implementation of the model (software development specific), to make sure the model behaves as designed. However, testing can also relate to validation – checking whether the model lives up to its purpose – for instance testing the results produced by the ABM against real data if the aim is prediction of the real world-state.
- **Internal validity**: in VBM this is to assure the causal relation between variables and their effect size. In ABMs it refers to the plausibility in assumptions and causal relations used in the model (design), e.g., by basing these on expert knowledge, empirical insights, or theory rather than on the modeller's intuition only.

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Differences. There are several differences when it comes to VBM and ABM. Firstly, there is a difference in what a model should replicate, i.e., the target of the model: in social psychology the focus tends to be on the relations between variables underlying behaviour, whereas in ABM it is usually on the macro-level patterns/structures that emerge. Also, the concept of causality differs in psychology, VBM models are predominantly built under the assumption of linear causality[3], with statistical models aiming to quantify the change in the dependent variable due to (associated) change in the independent variable. A causality or correlation often derived with "snapshot data", i.e., one moment in time and one level of analysis. In ABMs, on the other hand, causality appears as a chain of causal relations that occur over time. Moreover, it can be non-linear (including multicausality, nonlinearity, feedback loops and/or amplifications of models' outcomes). Lastly, the underlying philosophy can differ tremendously concerning the number of variables that are taken into consideration. By design, in social psychology one seeks to isolate the effects of variables, maintaining a high level of control to be confident about the effect of independent variables or the associations between variables. For example, by introducing control variables in regression models or assuring random allocation of participants in isolated experimental conditions. Whereas in ABMs, there are different approaches/preferences: KISS versus KIDS (Edmonds & Moss, 2004). KISS (Keep It Simple Stupid) advocates for keeping it simple as possible: only complexify if the simple model is not adequate. KIDS (Keep It Descriptive Stupid), on the other end of the spectrum, embraces complexity by relating to the target phenomenon as much as one can and only simplify when evidence justifies it. Either way, the idea of control in ABM is to avoid an explosion of complexity that impedes the understanding of the model, that can lead to e.g., causes misleading interpretations of emergent outcomes due to meaningless artefacts.

We summarise some core take-aways from our comparison discussions in Table 1.

Table 1. Comparing models in social psychology and agent-based social simulation

	Social psychology (VBM)	**Social Simulation (ABM)**
Aim	Theory development and prediction (variable level)	Not predefined. Can vary widely purpose. (system level)
Model target	Replicate and test relations between variables	Reproduce and/or explain a social phenomenon – the macro level pattern
Composed of	Variables and relations between them	Agents, environment & interactions
Strive for	High control, (low number of variables and relations Replication	Purpose-dependent. Model complexity: represent what is needed, not more, not less.
Testing	Hypotheses testing using statistics, including possible measuring the effect size a relation to assess confidence in the variable's importance'	Purpose-dependent. Can refer to verification, validation, sensitivity analysis or all of them. See text and refs under false friends.
Causality	(or correlation) between variables Linear representation	Between variables and/or model entities. Non-linear representation
Theory development	Critical reflection on theory through confirmation. Through hypothesis testing (a prediction) theory gets validated or (if not confirmed) input for reconsideration of the theory.	IFF aim of model, ways of doing is not predefined. It can be reproducing the theory prediction with or without internal validity. ABMs can further help to identify gaps in existing theory.
Dynamism	Little – often within snapshot causality	Core – within snapshot and over time causality
External validity(*the ability to say something about the actual target/ empirical phenomenon*)	VBM aims at generalisation and has predictive value for the phenomenon in focus. VBMs in lab experiments are often criticised for their weak external validity, considered high for field experiments.	ABMs insights are about the model, not directly about the real world. Without making predictive claims, they often do aim to say something about the real world.

Beyond blind spots, towards complementary powers

We shared the result of our discussions, the (seemingly) communalities and differences between models in social psychology and agent-based social simulation. We allowed for a peek into the content of our interdisciplinary journey as we invested time, allowed for trust to grow, and engaged in open communication. All of this was needed in the attempt to uncover conflicting ways of seeing and studying the social identity approach (SIA). This investment was crucial to be able to make progress in formalising SIA in ways that enable for deeper insights – formalisations that are in line with SIA theories, but also to push the frontiers in SIA theory. Joining forces allows for deeper insights, as VBM and ABM complement and challenge each other, thereby advancing the frontiers in ways that cannot be achieved individually (Eberlen, Scholz & Gagliolo, 2017; Wijermans et al. 2022,). SIA social psychologists bring to the table the deep understanding of the many facets of SIA theories and can engage in the negotiation dance of the formalisation process adding crucial understanding of the theories, placed in their theoretical context. Social psychology in general can point to empirically supported causal relations between variables, and thereby increase the realism of the assumptions of agents (Jager, 2017; Templeton & Neville 2020). Agent-based social simulation, on the other hand, pushes for over-time causality representation, bringing to light (logical) gaps of a theory and providing explicitness and thereby adding to the development of testable (extended) forms of (parts of) a theory, including the execution of those experiments that are hard or impossible in controlled experiments. We thus started our journey, hoping to shed some light on blind spots and releasing our complementary powers in the formalisation of SIA.

To conclude, we felt that having a conversation together led to a qualitatively different understanding than would have been the case had we all 'just' reading informative papers. These conversations reflect a collaborative research process (Schlüter et al. 2019). In this RofASSS paper, we strive for widening this conversation to the social simulation community, connecting with others about our thoughts as well as hearing your experiences, thoughts and learnings while being on an interdisciplinary journey with minds shaped by variable-based or agent-based models, or both.

Acknowledgements

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Notes

[1] Most VBMs are linear (or multilevel linear models), but not all. In the case of non-normally distributed data changes the tests that are used.

[2] We are researchers keen to use, extend, and test the social identity approach (SIA) using agent-based modelling. We started from interdisciplinary DFG network project (SIAM: Social Identity in Agent-based Models, https://www.siam-network.online/ (https://www.siam-network.online/)) and now form a continuous special-interest group at the European Social Simulation Association (ESSA) http://www.essa.eu.org/ (http://www.essa.eu.org/).

[3] ABMs can cater to diverse purposes, e.g., description, explanation, prediction, theoretical exploration, illustration, etc. (Edmonds et al., 2019).

Wijermans, N., Scholz, G., Paolillo, R., Schröder, T., Chappin, E., Craig, T. and Templeton, A. (2022) Models in Social Psychology and Agent-Based Social simulation - an interdisciplinary conversation on similarities and differences. *Review of Artificial Societies and Social Simulation*, 4 Oct 2022. https://rofasss.org/2022/10/04/models-in-spabss/

❮ **ABM** ❮ **ANNETEMPLETON** ❮ **COGNITION** ❮ **COMPARISON** ❮ **EMILCHAPPIN** ❮ **GEESKESCHOLZ** ❮ **GROUPS** ❮ **KIDS** ❮ **KISS** ❮ **MODELLING** ❮ **NANDAWWIJERMANS** ❮ **ROCCOPAOLILLO** ❮ **SOCIAL PSYCHOLOGY** ❮ **SOCIAL SIMULATION** ❮ **SOCIETY** ❮ **TERMINOLOGY** ❮ **TOBIASSCHRODER** ❮ **TONYCRAIG** ❮ **VARIABLE-BASED MODELS**

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