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Opinions on contested energy infrastructures: An empirically based simulation approach

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ABSTRACT

The dynamics of opinions are seldom investigated in detail in public opinion research because of the difficulty in capturing long-term changes with classical empirical methods. Agent-based modeling (ABM) promises a solution for combining (structural) theories and temporally explicit models while also considering social interaction. In this paper we operationalize and formalize the theoretical assumptions of the social judgment theory concerning opinion changes. Moreover, to link the ABM to a real case, we investigated opinions on the contested infrastructure of deep geological repositories in Switzerland with a longitudinal online questionnaire. The questionnaire results serve as initialization data for the model. The simulation results show the agents' opinions in a disaggregated way and reveal their heterogeneous development over time. The implications for a successful research cycle comprising theorizing, modeling, and empirical data acquisition are discussed.

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1. Introduction

> "Our technological powers increase, but the side effects and potential hazards also escalate."
>
> Alvin Toffler

As this quote suggests, the continuous progress in technology and science brings both new opportunities and novel challenges. Although such progress brings many benefits, we also need to be aware of the "side effects" that can emerge. This is true for environmental, social, and individual aspects. People are concerned about the rapid changes in our industrialized world and how such changes may affect the environment. Because policymakers must take public concerns into account, it is highly relevant to investigate how people perceive environmental topics, communicate with one another, and form their own opinions[1] (Venables, Pidgeon, Parkhill, Henwood, & Simmons, 2012; Visschers & Siegrist, 2014).

However, it is difficult to capture the dynamics of changes and adaptations in opinions over time. Generally, empirical research is often cross-sectional and therefore has major limitations when trying to explain the dynamic mechanisms of change in its dependent variables. Although longitudinal designs are helpful in overcoming this gap and generally should be applied more frequently (Siegrist, 2013), it is still a challenge to capture the development that may occur between the times of measurement. What may happen to opinions or specific arguments during these time intervals often remains unknown because tracking variables over long time periods (e.g., one year) is challenging. A recent review of longitudinal studies related to the public perception of climate change (Capstick, Whitmarsh, Poortinga, Pidgeon, & Upham, 2014) also pointed out that the time dynamics in the perception of environmental issues are crucial. How individual perceptions change and affect public opinion is an important issue for investigation. However, there is a lack of valid "before-and-after" measures on the basis of which hypotheses about this complex system can be formulated. Advanced techniques and interdisciplinary methodologies are required that allow for representative and satisfactory results. Theories about opinion changes can be applied to help with assumptions about the dynamics during the time intervals between empirical measurements.

Additionally, if we refer to complex environmental issues (e.g., climate change, biodiversity, and nuclear energy and waste), experimental designs are difficult to implement due to restricted external interventions. The influence of media information,

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[1] Since the terms "opinion" and "attitude" are often interchangeably used, we prefer the term "opinion" and define it as an overt evaluation—comprised by affective and cognitive elements—of a target or an object (for an overview, see Maio & Haddock, 2010).

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political scandals, and even dramatic events, such as a nuclear incident, are relevant for changes in opinions; however, their operationalization in an experiment is very challenging. Another limitation is the lack of investigation regarding the potential of the mutual influence of individual and public opinions. It is still a challenge to investigate how public opinion arises, the extent to which it is subject to change, and how precisely it influences opinions at an individual level. Including social simulations is a way to at least partly overcome these drawbacks (see e.g., Ernst, 2010; Squazzoni, Jager, & Edmonds, 2014).

Our study aimed to combine sociopsychological theory and empirical research with social simulation to improve the methods of investigation of opinion dynamics related to a specific issue.

1.1. Social simulation models

1.1.1. Why should we use social simulation?

Models are used to purposefully represent a real system in order to answer questions and solve problems related to this system. Because of the high complexity of such systems (e.g., cities, landscapes, populations), modelers assume the challenge of formulating algorithms and assumptions that best represent the real system by keeping the model simple enough to understand and experiment with (Railsback & Grimm, 2012; Starfield, Smith, & Bleloch, 1990). Each model focuses on determined aspects that are related to the own purpose. It is therefore important to determine the utility and goal of each and every model.

Epstein (2008) pointed out the relevance of simulation models and argued against considering them solely a prediction tool. In response to the question "Why model?", Epstein (2008) listed 16 reasons for using models, including the following: *guidance of data collection, illumination of core dynamics and uncertainties, discovering new questions,* and *revealing the apparently simple (complex) to be complex (simple)*. Simulation is a powerful methodological tool that can be utilized to explore phenomena and answer various questions. However, it is essential to integrate the simulation approach appropriately into the scientific domain of interest. For instance, if we want to investigate social phenomena, we should keep in mind that social theories and their contents are core elements that need to be integrated into social simulations. This allows for models that can help to investigate complex social dynamics and identify some of the factors that lead to specific social phenomena (Squazzoni et al., 2014). Social simulation is a useful tool of investigation for exploring questions about social interaction, the interaction between humans and their environment, behavioral and cognitive processes over time, and emergent social phenomena at the macro-level (Ernst, 2010). In particular, the constraints of empirical investigations and experimental settings can be overcome with social simulations. Some constraints relate to the impossibility of changing numerous variables in an experimental setting, the risk of biases due to very complex environments, and the limited investigation of dynamics and interactions between individuals. Using social simulations, one can change numerous variables and conduct several simulation runs in a relatively short time; simulate social interactions and build complex environments; and investigate the processes over time, allowing for assumptions about the dynamics of the investigated issue (Jager & Mosler, 2007). A major question remains, however, regarding how to best construct a good model by taking into account existing theories and empirical evidence.

1.1.2. Modeling opinion dynamics

The topic of opinion dynamics addresses the question of how opinions change over time, based on social interactions. A well-known model of opinion dynamics is the Deffuant-Weisbuch model (Deffuant, 2006; Deffuant, Neau, Amblard, & Weisbuch, 2000). In this social simulation model, opinions situated in an artificial continuous opinion space (from "against" to "in favor") are exchanged in interactions among an artificial population. Binary interactions are thought to have occurred when the difference in opinion is below a threshold that is arbitrarily set in the social network in which each agent is located. Variations in the thresholds show either the convergence (high threshold) or the emergence of opinion clusters (low threshold). Although this model is neither based on any psychological theory or empirical data nor refers to a specific topic for practical application, it shows how abstract models can help in understanding social system dynamics. A factor that underlines this statement is the effect of emergence (the agents form opinion clusters) and downward causation (the effect observed at the macro-level is caused by the single agent over the interactions) that is described in the model (see Gilbert, 2010 for an overview). Other scholars considered the theoretical foundation of opinion dynamics. For instance, Jager and Amblard (2004) incorporated social judgment theory (SJT) (Sherif & Hovland, 1961) into a model for attitude dynamics to simulate the effects of assimilation and contrast (see section 1.2.1. for details about the theory) in a persuasion interaction. Jager and Amblard (2004) demonstrated that the attitude structure of the agents (i.e., thresholds determining the latitudes of acceptance and rejection) was the determining factor for the occurrence of assimilation and contrast effects. These effects caused the agents in the model to reach consensus (high latitude of acceptance, small latitude of rejection), hold two extreme attitudes (i.e., small latitude of acceptance, high latitude of rejection), or form subgroups of individuals sharing the same attitudes (i.e., pluriformity) when both latitudes of acceptance and rejection were small (i.e., high latitude of non-commitment). Other research included the element of rejection in an opinion dynamics model (Huet, Deffuant, & Jager, 2008). When the attitudes of the agents were either far or close to each other, the rule of bounded confidence from the Deffuant-Weisbuch model (Deffuant et al., 2000) was applied (meaning that only agents within a determined confidence level set by the model rules were taken into account; see also Hegselmann & Krause, 2002; Krause, 2000). However, when the attitudes assumed a discrepancy (one is close and the other is far), this caused rejection and thus a shift away from the other's attitude.

These examples show that opinion dynamics can be investigated via social simulation models. However, the assumptions made in these simulations most often rely on arbitrary values and exclude real data. Including psychological theories combined with empirical data in a simulation can fill this gap and provide results for the simulation models that better represent real systems (which is one of the main aims of simulations) and real opinion dynamics regarding a specific topic. However, determining how to actually create this combination is in itself a challenge and is seldom pursued. We need to complement and adapt each of these methods for satisfactory results. In this paper we share some insights and illustrate the challenges of the mutual adaptation of empirics, theory, and a simulation model.

1.2. Theoretical background

1.2.1. Psychological theory

There are theoretical approaches in psychology that explain the underlying processes that may occur during interactions between individuals. Popular models, such as the elaboration likelihood model (ELM) (Petty & Cacioppo, 1986) or the heuristic systematic model (HSM) (Eagly & Chaiken, 1993), have found many applications in empirical research. However, these models are too complex to be included in a simulation model in combination with empirical

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