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Moderate and Polarized Opinions. Using Empirical Data for an Agent-Based Simulation

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Abstract — **The selection of a potential site for a deep ground repository for nuclear waste in Switzerland is designed as a participatory process where the citizens' opinions play a central role. Understanding how Swiss citizens form and change their opinions over time on this specific issue is this study's main goal. For this purpose, different methodological approaches are needed. First, a longitudinal online survey based on an argumentative approach aims to show the main dynamics and changes of the opinions over time. Second, an agent-based model simulates opinion changes based on the empirical data and sociopsychological theories. Results of the online survey show the replication of a four-opinion cluster (i.e., in favor, opposing, ambivalent, indifferent) and the relevance of using the dimensions of valence and importance for the arguments. The implementation of the agent-based simulation is discussed.**

I. INTRODUCTION

IN democratic countries, the opinions of citizens and major social groups are of central relevance for all sorts of political and social decisions. This implies that citizens need to form their own opinions about different topics. Various fields in the social sciences provide theoretical considerations about how people form and exchange their opinions. However, the question about the factors and the dynamics that people assume to form opinions on specific issues still needs to be clarified.

The storage of nuclear waste is an example of a controversial topic on which citizens of a country are asked to provide their own opinions [1]. For the purpose of examining the structure of opinions related to this issue, the prevailing method is to use polarized opinion scales that merely differentiate between proponents and opponents [2], [3]. An investigation on moderate positions (i.e., ambivalence and indifference) is mostly neglected [4].

More recent studies [5] showed that the opinions about a potential deep ground repository (DGR) for nuclear waste (the results of individual ratings on risk and benefit scales) can be clustered into four groups:

- high-risk ratings *opposing* a DGR;
- high-benefit ratings *in favor* of a DGR;
- *ambivalence* (high ratings on both risk and benefit scales and moderate opposition);
- *indifference* (moderate ratings on both risks and benefits, compared to the ambivalent cluster, and a moderate acceptance).

This risk and benefit approach provides aggregate results that are difficult to interpret in a more process-oriented view. Even though one might include moderate opinions, the mechanisms of opinion dynamics remain vague. For this reason, we need to examine more detailed structures of opinion formation and dynamics by using an argumentative approach [6], [7]. The rationale behind this is that in real life, people usually do not interact by sharing their mean values on risk and benefit scales on a topic, but by exchanging arguments that they value in a certain way. This manner of evaluation can occur using the dimensions of *valence* (i.e., how in favor or how against arguments are regarding the specific topic) and *importance* (i.e., how unimportant or important the arguments are rated regarding a specific topic).

Moreover, we need to explain how people build these structures and eventually adapt them after their interactions. Therefore, we require a review of psychological theories that can explain such mechanisms. A plausible, underlying sociopsychological mechanism for opinion formation is described by the Social Judgment Theory (SJT) [8]. This theory explains how an individual weighs new beliefs, attitudes, and/or cognitions by comparing them with his or her own current point of view. This process takes place among three judgmental *latitudes*:

- *acceptance*, including the positions that an individual finds acceptable. In this case, a shift in the direction of the advocated position (assimilation) is possible;
- *rejection*, including the positions that an individual finds unacceptable. In this case, a shift in the opposite direction of the advocated position (contrast) is possible; and
- *non-commitment*, including the positions that an individual neither accepts nor rejects.

As this theory posits, a change in opinion will more probably take place in the latitude of non-commitment and

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the proximate transitions to the latitudes of acceptance and rejection—which is comparable to the range of moderate opinions. The SJT has mainly been tested in small experimental settings, only rarely in more extended ways that include an investigation of opinion changes on a collective level in modeling studies [9]. Our study aims to operationalize this theory in relation to a specific issue (see below) and to integrate it into a simulation model.

From a methodological point of view, the investigation of *opinion dynamics* is limited if we rely solely on empirical methods such as single surveys and experiments. Many researchers pointed out the relevance and usefulness of computer simulations [10], [11]. These simulations have already found some significant applications in social psychology [12]. Specifically, some successful applications of opinion dynamics in the field of computer simulation, mainly based on agent-based models (ABMs), have already emerged [13], [9]. The ABM approach can be useful for testing the underlying mechanisms of both the change and the structure of opinions. This step can lead to a more complete investigation that can shed light on dynamic aspects on both individual and collective levels.

Our assumption is that moderate positions can be key elements for a deeper understanding of the formation and development of opinions. This leads to the questions: Where are the tipping points of public opinion that can lead to changes in individual opinions? How can we define the emerging patterns of public opinion in a heterogeneous population?

In our study, we address these research questions in relation to Switzerland's case. For several decades, Switzerland has been producing nuclear waste (e.g., nuclear power plants and industries) that is currently stored in two interim facilities in the country. However, for long-term storage, the best-known scientific solution relies on DGRs. The Swiss government is currently leading a process of geological selection for a potential DGR site for nuclear waste. This process is designed to be participatory in order to gain public acceptance; therefore, it places considerable emphasis on public opinion and the question of how citizens form and eventually change their opinions over time on this topic.

We present the first steps of a quantitative investigation about the different opinions on a DGR in Switzerland and the first attempts at an ABM that can simulate opinion changes over time.

II. METHODS

Our investigation's methodology includes an empirical part as well as an ABM. First, we provide an overview of the empirical part and then describe in detail the content of the multi-agent system.

A. Empirical Part: Longitudinal Online Survey

The empirical part consists of the first wave of investigation using a longitudinal online survey, in which 1,302 German-speaking Swiss citizens participated. After an introduction to the topic and the collection of demographic data, participants rated ten arguments (eight adapted from risk and benefit scales regarding nuclear waste and DGR used in past literature [4] and two referring to the ongoing political process) on a *valence scale* (i.e., against or in favor of DGR in Switzerland) and an *importance scale*. The ten arguments in the online survey are categorized into three types (see Table 1).

For the purpose of investigating the latitudes described in the SJT (i.e., acceptance, non-commitment, and rejection), participants completed an alternative ordered scale [8]. This scale allows the differentiation of the three latitudes by asking the participants to rate the arguments on a ranking from "the most acceptable" to "the most objectionable."

TABLE I.
THREE ARGUMENT TYPES

Risk-Oriented (RO) Arguments	**Benefit-Oriented (BO) Arguments**	**Process-Oriented (PO) Arguments**
Four arguments regarding the primarily risky aspects of a DGR.	Four arguments regarding the primarily beneficial aspects of a DGR.	Two arguments regarding the political process for the site selection of a DGR.

B. Computer Simulation Part: Agent-Based Model

To report our ABM we follow the overview, design concepts, and details (ODD) protocol put forth by Grimm et al. [14]. For the implementation, we use the NetLogo 5.0.3 software.

a) Purpose

This ABM's purpose is to simulate the opinion dynamics regarding the DGR and nuclear waste issue in Switzerland. The model shows how opinions can shift due to the interactions between agents. In such interactions, agents compare arguments on the basis of a sociopsychological theory; over time, they adapt (or not) their opinions, depending on the interactions in which they were involved. This process should offer insights into the dynamics that lead to changes in the opinions of individuals, as well as show how moderate and polarized opinions become influenced by these dynamics. The results should help explain potential opinion changes during the site selection process for a DGR in Switzerland.

b) Entities, state variables, and scales

Agents represent individuals from the German-speaking Swiss regions. Each agent possesses a given set of arguments, currently limited to three types (i.e., *risk-oriented [RO], benefit-oriented [BO], and process-oriented [PO] arguments*) for the purpose of simplicity. The three argument types are the same for every agent to make comparisons possible. Each argument type x is described as a function Arg_x [-1 – 1] of the mean values of valence V_x (on a continuum from positive to negative, representing the positions from -1 "absolutely against" to 1 "absolutely in favor" regarding the topic of a DGR) and the mean values of importance I_x (from 0 "not important at all" to 1 "very important"). The equation is shown below:

$$Arg_x = V_x * I_x \quad (1)$$

One interaction between two agents occurs in one time step.

c) Process overview and scheduling

Agents interact randomly with each other and compare their argument types (i.e., *RO*, *BO*, and *PO*) in a one-directional interaction. Based on the SJT, each agent first decides whether it accepts or not the argument type of the other agent by checking if the value for Arg_x lies in the latitude of rejection. Depending on the position of the argument type compared to an agent's own latitude, it subsequently decides whether it adapts or not its own value away or toward the other's value. When it finishes the comparison, it exits the interaction and chooses a new agent for the next interaction (see Figure 1).

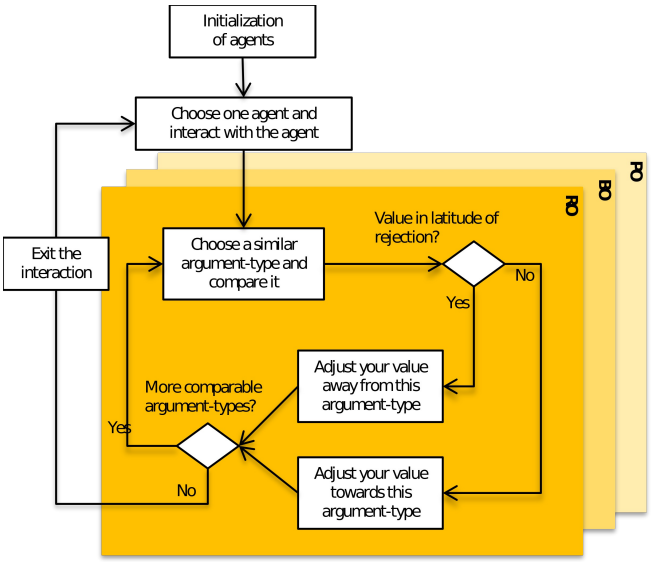

Figure 1. Flow chart of the interactions

d) Design concepts

This model aims to simulate the opinion dynamics based on the interactions between agents. During initialization, agents are randomly linked together in order to create a basic social network (i.e., small world). At each time step, each agent exchanges its argument type with that of a randomly chosen neighbor and changes its own opinion in response to its adaptation after an interaction. All the argument types possess two dimensions: *valence* and *importance* (see Equation 1). The *general opinion on DGR* results in the mean value of every argument type value Arg_x. During the interaction, the interacting agent compares the other's argument type with its own and evaluates how far these argument types are from each other. Depending on this distance (i.e., the latitudes), the agent decides to shift its own argument type value away or toward the other's argument type. This process is repeated for each argument type during one interaction.

As an objective, each agent strives to build its own solid opinion about nuclear waste repositories. This objective is related to the amount of adaptation the agent experiences; the less the agent adapts after interactions, the more its opinion becomes solid.

The social network is updated after every interaction (time step). New links are created (with agents holding arguments that mostly fall under the latitudes of non-commitment and/or acceptance), and others are broken (with agents holding arguments that mostly fall under the latitude of rejection).

e) Initialization

Each agent has its state variables assigned at the setup procedure, based on the empirical data from the online survey. The following variables are needed to set up the agents' profiles:

- values for the valence of each argument type (V_x);
- values for the importance of each argument type (I_x); and
- ranges for the latitudes of rejection, non-commitment, and acceptance of each argument.

III. Results

The first analysis replicated a four-opinion cluster solution that was observed in prior investigations. The four clusters represent different types of opinions (i.e., *opposing, in favor, ambivalent, and indifferent*), based on the evaluation of the arguments.

Concerning the latitudes described by the SJT, the results of the alternative ordered scale revealed that people evaluate the arguments on being on different latitudes across the continuum, ranging from rejection to acceptance. However, the process-oriented arguments were found to be predominantly in the latitude of acceptance.

The ratings for importance showed higher values for process-oriented arguments than for risk-oriented ones, and the lowest values for benefit-oriented ones.

A. Expected Simulation Results

Based on our simulation described above, we expect to have heterogeneous agents with different values for the three argument types. These values will result in the four types of opinions comparable to the empirically based, cluster analysis solution (i.e., opposing, in favor, ambivalent, and indifferent). Each agent with its own set of three argument types will then interact with another agent per time step and compare the values of the argument types using the latitudes described by the SJT. We expect a change of opinions from moderate to more polarized ones at the agent level, due to the evaluations of the argument types on the latitudes. Those agents with argument-type values that are predominantly in the middle position (around zero) are anticipated to adapt more than their counterparts with argument-type values that are primarily in the upper or lower ranges (either -1 or 1), depending on the other agent's argument-type value.

The argumentative approach should lead to more realistic dynamics that simulate the interactions among people who discuss the site selection process for a DGR in Switzerland, by tracking the changes in their opinions based on the comparison of different arguments.

IV. Discussion

This study provides results that can help define the dynamics and mechanisms of opinions regarding the specific issue of nuclear waste and DGR. The arguments that are rated on valence and importance, in combination with the sociopsychological assumptions of the SJT (although challenging to operationalize and investigate), constitute a valid and realistic approach for examining opinions on this specific issue. Together with the methodological combination of a longitudinal online survey and an ABM, this study allows the investigation of dynamic aspects that are often neglected in more methodologically homogeneous designs.

From our preliminary analyses, we observe that focusing on arguments, instead of mere risk and benefit evaluations, can provide more detailed insights into the underlying structures of opinions. By having two dimensions for each argument (i.e., *valence* and *importance*), we could provide a differentiation of the structure of opinions, which is important if we want to draw the investigation closer to the real process of opinion dynamics among the citizens of a country. Moreover, we can distinguish the set of arguments for different types (risk-, benefit-, and process-oriented arguments); this can offer in-depth knowledge about how people perceive the site selection process for a potential DGR in Switzerland, which is obviously of high relevance in the ongoing political process.

The implementation of the ABM provides a basis for investigating the dynamics that would otherwise be difficult to measure with common methods in the social sciences (e.g., questionnaires, experiments, etc.). The model will be validated with the upcoming phases of the longitudinal online survey.

A. Next Steps and Further Investigations

The next steps for this study concern an in-depth analysis of the empirical data and its implementation in the ABM. To obtain robust results from the simulation, further trials and analyses are necessary (sensitivity analysis). The next stages of investigation using the longitudinal online survey can provide additional data for the model validation, which is crucial for a powerful simulation. Additionally, a more differentiated initialization of the agents could lead to more precise process dynamics, by considering other traits, such as gender or age differences, expertise, or involvement. Exogenous processes (e.g., influences of the media) will also allow a further step for a more realistic representation of the model.

We are currently working on the next steps and have confidence in our ability to present more detailed results during the conference session in September 2014.

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