Editorial: Modelling Values in Social, Technical, and Ecological Systems

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Abstract: This editorial paper for the special section on "Modelling Values in Socio/Technical/Ecological Systems" introduces interdisciplinary perspectives on values and reflects on growing appeals for modelling values. In public and academic discourses, values typically relate to matters of importance (e.g., beliefs, priorities) and principles about what is considered to be good (e.g., moral values) and are often seen as shaping individual and collective behaviour. As shown by eight contributions to this special section, it is relevant for social simulation modelling to dive deeper into embedding values in models in order to explore behavioural change on different levels and across contexts. Our goal with this special section is to stimulate interest in developing various approaches that study and operationalise values in agent-based models to investigate the complex problems raised in social, socio-technical and socio-ecological systems. We conclude with a call for future research to be explicit in their modelling assumptions, thus fostering a vigorous foundation for scientific discourse.

Keywords: Values, Value Change, Socio-Technical Systems, Socio-Ecological Systems, Agent-Based Modelling

This article is part of a special section on "Modelling Values in Socio/Technical/Ecological Systems", guest-editors: Amineh Ghorbani, Anna Melnyk, Bruce Edmonds, & Ibo van de Poel

Introduction

1.1 "Why bother about modelling values?" - you may wonder while reading the name of this special section. Values are complex notions that provide insights into why people do what they do and "what matters to them." A systematic literature study by Gould et al. (2023) revealed that values and related constructs comprise approximately one-third of overall constructs in 134 behaviour theories and that they play an essential role in understanding behavioural change. By and large, the social sciences and humanities claim values to be one of the important elements in understanding wicked problems, especially due to the disagreements and controversies that can be a result of the different values in societies (Gould et al., 2023) or value change (Melnyk, 2022). Values are relevant for understanding new dilemmas that have emerged as societies face the implications of climate change (e.g., floods, droughts) (e.g., Gardiner, 2010), energy crisis (e.g., Melnyk et al., 2023; Perlaviciute et al., 2018), extensive digitisation (e.g., van de Poel, 2020), increasing inequalities (e.g., Devillers et al., 2021), opinion dynamics (Lorenz & Neumann, 2018) and the COVID-19 pandemic (e.g., Steinert, 2021). Dealing with these new social, environmental, and technological challenges requires a comprehensive approach to system change (e.g., technological system, ecosystem, social system), including cooperation among people, so values that affect that cooperation are crucial. Thus, an inquiry into values is essential for gaining insights into the patterns of behaviour and the potential pathways in navigating these system-level challenges since such system

changes (macro-level) also require behavioural changes (micro-level), which can drive underlying changes in values (Correljé et al., 2022; van de Poel, 2018).

1.2 A recent development is the usage of simulation models to perform explorations, analyses, and assessments of socio-technical and socio-ecological systems based on the different conceptual standpoints and empirical data about values. Alongside other approaches, simulation models can help understand the implications of fundamental theories of value in social sciences and humanities and increase the scale of such studies. Agent-based modelling is particularly suitable in this context as it can capture the multilevel complexity of complex socio-cognitive phenomena (Dignum et al., 2022), involving both emergent and aggregated phenomena (up-wards causation) as well as the influence of the macro-social level on individuals via their values (downwards causation). Its multi-level ability allows it to mediate between several academic disciplines and perspectives on values (e.g., Boshuijzen-van Burken et al., 2020; Mercuur et al., 2019; de Wildt et al., 2021; Kreulen et al., 2022; Harbers, 2021), which is why agent-based modelling and the study of values go well together.

1.3 We invite our readers to dive into exploring the role of values in individual and collective decisions, actions, and behaviour, as well as on the system level, in the field of social simulation and agent-based modelling. The goal of this special section on modelling values is to stimulate interest in the development of ontological, method-ological, and epistemological approaches that study and operationalise values in agent-based models (ABMs) to investigate the complex problems raised in social, socio-technical and socio-ecological systems and to report on pieces of work that contribute to this area.

1.4 In the next sections, we introduce various theoretical and empirical perspectives on values, reflect on the use of these theories in ABMs, and provide a brief sketch of the evolution of relationships between values and models in the philosophy of science. We finish by offering an overview of contributions to this special section and extend an invitation to continue research in modelling values.

Different Perspectives on Values and Their Dynamic Nature: Theoretical and Empirical Support

2.1 Scrutinising different theoretical stands on values and value change in agent-based modelling requires a more elaborate classification of what theories of value exist and how such theories in ABMs are or can be used. Whereas recent social simulation developments concern various applications of theories within agent-based models (Scholz et al., 2023; Antosz et al., 2023), no systematic approach for the use of theories of values has been proposed. In the following, we will briefly introduce some of the theoretical and empirical perspectives on values and reflect on what they imply for value change.

2.2 Although the idea of values traces long back to the Ancient Greek philosophical dialogues (Seung, 1996), social sciences and humanities are experiencing a renewed interest in the notion of values (Steinert, 2023; Martin & Lembo, 2020) and their dynamic nature (van de Poel, 2018, 2022; Steinert, 2021). In an attempt to understand why people behave the way they behave, scholarship in the social sciences typically distinguishes three dimen-sions of values (personal, social, and cultural), as well as moral values (Steinert, 2023). The variety of ways in which values can be conceptualised or understood can result in confusion. Values have been defined as rel-atively stable beliefs (Schwartz, 1992; Davidov et al., 2008) or as attitudes (Martin & Lembo, 2020), but values also have moral relevance as they help to understand the connection between ought and is. What are morally permissible values? They seem to change over time, for instance, in the example of the abolition of slavery (An-derson, 2014; Jamieson, 2002). Although, some would claim that in this example, social values have changed, but moral values (what is morally permissible) have not.

2.3 Other studies claim that values are "explanatory devices" shedding light on why people do what they do and providing insights into people's decisions (Ravlin & Meglino, 1987), behaviours (Gould et al., 2023), and actions (Parsons, 1935). Yet another perspective suggests values are principles containing normative force that, in addi-tion to the individual level, should be studied on the collective level, as they may link to social norms (Hansson, 2001) and norms change (Bicchieri, 2016). Thus, applying theories about values within agent-based simulations is needed, not only in that otherwise an important dimension of human decision-making might be missing but also because making these theories formally precise within simulations might help establish the differences between these accounts.

2.4 Of course, it is no good for modellers to implement these within their simulations if the theories turn out to be wrong or badly formulated, so the extent of their empirical support and their scope are important. The degree of empirical support for different theoretical perspectives on values and value change varies across disciplines like psychology, anthropology, sociology, and philosophy, which we now briefly discuss in turn.

1. In **psychology**, values combine i) "a motivation for the initiation and maintenance of behaviour, and ii) an evaluative attitude that influences the perception and evaluation of things" (Steinert, 2023, p. 12). Individual beliefs and values are relatively stable and seem to form an interrelated hierarchical system that guides a person or a group to a desirable goal (Schwartz, 1992). Schwartz (1992), Schwartz (1994) proposed a value typology comprising 56 values based on the input from a cross-cultural value survey. Based on this empirical data, it was found that values can be grouped into 10 clusters that describe individual differences in value priorities: conformity, tradition, universalism, benevolence, power, achievement, hedonism, stimulation, self-direction, and security. Furthermore, there are studies that trace cross-cultural patterns of value priorities (Davidov et al., 2008). Psychological studies suggest that values are typically formed before reaching adulthood and may change only in case of significant crises (Steinert, 2021, e.g., Covid-19) and "life-changing" events like moving abroad (Bardi et al., 2014; Sagiv et al., 2017). Due to extensive empirical grounding, psychological theories of values are the most popular among agent-based modellers (e.g., Gore et al., 2019; Boshuijzen-van Burken et al., 2020; Beheshti & Sukthankar, 2014; Kreulen et al., 2022), including contributors to this special section (e.g., Czupryna et al., 2024; Ale Ebrahim Dehkordi et al., 2024; Davis et al., 2024; Jager et al., 2024; Shults et al., 2024). However, psychology typically takes an individual perspective or aggregated individual perspectives on values and so does not study what might happen in more social settings.

2. In **sociology**, values are sometimes referred to as broad propensities that incline toward a specific state of affairs over others or as principles (Martin & Lembo, 2020). Weber (2013) distinguishes social value realms that can be categorised into groups (e.g., political, economic, religious, etc.). Other sociologists claim values belong to culture and are central to the theory of action (Parsons, 1935). For Parsons (1935), values are ends in themselves conceptualised in terms of what is desirable. Based on this theoretical perspective, however you look at values, they seem to play a role in navigating human social behaviour and decision-making. Another way to understand values has been proposed by Hofstede (2020), who linked values to cultures and used factor analysis to conclude with six value dimensions: Individualism and Collectivism, Power Distance Index, Uncertainty Avoidance, Masculinity vs. Femininity, Long Term vs. Short Term Orientation, Indulgence vs. Restraint. Perhaps the most influential empirically grounded sociological theory of values that also reflects on value change was proposed by Ronald Inglehart, who was the main researcher behind the World Value Survey. Based on survey results, this sociologist claims that one can currently observe a change from materialistic values to post-materialistic ones where things like environment and social justice prevail (Inglehart, 1997). In the context of agent-based modelling, the sociological perspective can be combined with the psychological one to bridge the gap between individual influence and collective phenomenon (Vanhée & Dignum, 2018), for example in studies in the context of the COVID-19 pandemic (Kreulen et al., 2022). The sociological perspective tends to pass over what is happening at the individual level and focuses more on the macro- or social levels of the effect of values.

3. **Anthropological** studies, among others, focus on collective differences in what people consider desirable (including values) across cultures (Steinert, 2023). In addition to that, anthropologists also study value orientations "a structured and general blend of normative elements (i.e., values in the sense of desirable) and disruptive assumptions about nature, human's pace in nature, human existence, the human-human relationship, and time" (Steinert, 2023, p. 56). Two main traditions in studying values are distinguished among anthropologists: structuralist and action-based accounts; there are also combinations of the two. Structuralists conceive values as embedded in mental structures and study the structures that "contribute to creating the categories and concepts of societies" (Steinert, 2023, p. 56). Within action-based accounts, agency plays a central role in value creation, and human action is seen as a source of value (Graeber, 2001). Although not many agent-based models have been built (explicitly) based on anthropological theories of values, such theories offer a rich empirical basis as well the possibility to connect action and culture. Even if anthropology usually does not seek formal accounts that allow rigorous exploration and testing, it provides a rich resource from which agent-based simulation could draw.

4. While in the above-mentioned perspectives, values are typically studied descriptively, in **philosophy**, they are also regarded as a normative phenomenon. Values can be conceived as abstract uncountable nouns (e.g., good), as (plural) countable nouns (e.g., sustainability, justice, privacy), as concrete nouns (e.g., a just society, a beautiful painting), and as a verb (valuing activity) (Pauls, 1990). Axiology – the philosophical study of values – mostly deals with values depicted as countable abstract nouns, such as justice, sustainability and privacy. Such values can be conceptualised as sets of standards, criteria and merits that contain normative power in terms of which evaluation, comparison and assessment of certain choices is made. Values manifest in certain goods, duties, and obligations and navigate decision-making by prescribing a fundamental basis for individual or collective moral guidance (Pauls, 1990). Although

empirically not very well-grounded, values are referenced in statements where "the emphasis lies on the object (the forest, nuclear arms) that is evaluated" and where values are referenced in "the evaluations of some object or phenomenon" (Pauls, 1990, p. 4). Many philosophers further distinguish between intrinsic and instrumental values (Zimmerman, 2015; Jamieson, 2002). Some scholars defend the idea of value pluralism in opposition to value monists, who claim that all values are reducible to one overarching value (Berlin & Hardy, 2002); pluralists claim that unresolvable tensions may originate from value conflicts.

Due to its very abstract nature, it can be hard to relate philosophical accounts to observations or more formal theories. Hence, exploring the concrete consequences of such philosophical accounts concerning specific issues or problems may be difficult.

Value change has recently received more attention in the philosophical literature, e.g., as a part of larger discussions on moral change (Eriksen, 2020; MacAskill, 2015). Specific examples are Dewey's account of value change featured in this special issue (see de Wildt & van de Poel 2024) and the discussions in analytical debates on climate ethics (Jamieson, 1992, 2002; Singer, 2011).

In the context of the ethics of technology, discussions about value and value change are usually less abstract and focus on technologies and socio-technical systems. In the context of socio-technical systems, discussion on value change can be found in research on the ethics of design and governance of new and emerging technologies (Boenink et al., 2010; Swierstra et al., 2009; Swierstra, 2013; Melnyk et al., 2023; Danaher, 2021; van de Poel, 2020). van de Poel (2018) distinguishes five types of value change: the emergence of new values, change of value conceptualisation, change in values prioritisation, change in the relevance of value for design and change in how values are translated. Interestingly, the simulation model developed by de Wildt et al. (2021) deploys the normative perspective on values in the context of value conflicts in the energy transition. For the current special section, we see this perspective in the context of technologically induced moral change (de Wildt & van de Poel, 2024) and in combination with psychological value theory aiming at exploring institutional emergence (Ale Ebrahim Dehkordi et al., 2024). This highlights the importance of developing agent-based simulations regarding philosophical accounts of values and value change.

● Values and Models

3.1 In the philosophy of science, the relationships between values and models have been scrutinised for at least sixty years. Some of the literature emphasises the basic representative feature of models and perceives the models straightforwardly as a representation of a specific target system (Giere, 2004). Based on this perspective, values would be seen as having an external role in evaluating the scientific practice of modelling. Simplicity, integrity, and scientific soundness – are ***epistemic values*** that typically pinpoint the standards of excellence for the evaluation of scientific practice. Scholars like Morgan & Morrison (1999) found such perspectives on models unsatisfying and highlighted the additional features of models in scientific practice, where it is possible to perceive models as mediators and as instruments of investigation. In other words, they suggest that models are a good learning playground, being mediators for scientists that make possible manipulation and exploration of the target system without necessarily intervening in the real world.

3.2 However, the "models as mediators" view is a very permissive take on models since even wrong models could help "mediate." Thus this view of modelling has a strongly relativistic flavour – according to this viewpoint, one cannot "improve" a model by, for example, debugging it; all one gets is a different mediator. Although we do not share Morrison & Morgan's perspective on modelling as we consider it to be ultimately vague, building a model requires many assumptions, decisions, and choices about which aspect of the modelled phenomena are represented and which variables are included. Such a perspective on modelling practice raised concerns about ***non-epistemic values*** that impact modeller's value judgment when making certain assumptions (Thompson, 2022). The personal values, beliefs, and moral standpoints of scientists may significantly impact how such choices are made and are often subject to implicit biases (Elliott & McKaughan, 2014).

3.3 In social simulation and agent-based modelling, values are not just external to the modelling process. Within explorations of human or system behaviour, explicitly ***embedded values*** on micro and macro levels are also components of the models themselves and represent social, socio-ecological and socio-technical elements. Complex challenges such as social justice, inequality, and climate change have a defining influence on our contemporary world and often irrevocably change the social, ecological, and technical systems we inhabit, making agent-based modelling a good method for interdisciplinary inquiry into such complex phenomena (Axelrod, 2006). Agent-based modelling is widely used to study complex adaptive systems (Holland, 1992), such as energy

systems and other socio-technical systems (Chappin et al., 2020); it is also widely used within climate change scholarship, e.g., to study socio-ecological systems (see Torren-Peraire et al., 2023; Gotts et al., 2019; Guerrero & Castañeda, 2022; Jager, 2021), and it is used to study behavioural change (Hailegiorgis et al., 2018; Kniveton et al., 2011) and the impact of climate-energy policy (Castro et al., 2020; Savin et al., 2023). Still, explicitly embedding values in ABMs is not yet common practice.

3.4 However, in addition to the relevance for understanding decision-making, action, and behaviour (Gould et al., 2023; Parsons, 1935) on individual and collective levels, values are particularly important when modelling how technologies and systems are being developed, appropriated, and used. In the context of the ethics of technology, it is widely acknowledged that values do not only stem from actors but can also be embedded into institutions and technologies by engineers and policymakers (van de Poel, 2009; Melnyk et al., 2023). In this context, inquiry into value change is particularly relevant as many existing systems, like energy systems that run on fossil fuels, no longer meet the values relevant today, like sustainability (van de Poel, 2018, 2022; Melnyk et al., 2023). In addition to that, values are essential for understanding technologically induced value change (Swierstra et al., 2009) and the relationships between value change and institutional change (Milchram et al., 2019; Correljé et al., 2022). Within this direction, exploration of the impact of values and related mechanisms within agent-based models has only recently gained traction (e.g., Mercuur et al., 2019; Boshuijzen-van Burken et al., 2020; de Wildt et al., 2021; Harbers, 2021). These studies show that embedding values in ABMs provides new insights.

3.5 So far, at least four patterns in modelling values that align explicitly or implicitly with different modelling purposes (Edmonds, 2017) can be found. First, simulation models can be used to understand and illustrate the possible societal impact of technologies in terms of values (de Wildt et al., 2021, 2019). Second, simulation models can be used to compare and demonstrate the effects of the application of ethical principles in infrastructure development (e.g., Ciullo et al., 2020). Third, studies exist that combine agent-based modelling with Value Sensitive Design to explore value tensions and value conflicts in technological governance and design (Harbers, 2021; Boshuijzen-van Burken et al., 2020; Mercuur et al., 2019). Fourth, values are used for illustration purpose to support the understanding of emerging responses to crises like the COVID-19 pandemic (Kreulen et al., 2022).

3.6 Hence, assumptions about the role of values in existing ABMs and their conceptualisations are (at least partly) based on some kind of theoretical and empirical grounding. This can be an explicit reference to a certain theoretical perspective on the nature of values or an implicit assumption about what values are that is inspired by particular theoretical perspectives or empirical insights.

● Contributions to the Special Section

4.1 Contributions to this special section demonstrate the various contexts in which values are relevant. Ranging from pandemic management, its economic impacts and institutional responses, opinion dynamics, and large-scale dietary changes and not limited by explorations of technological developments, contributions to this special section demonstrate the insightfulness of different theoretical and empirical perspectives on values for simulation modelling. These contributions also pinpoint the importance of incorporating values to better understand societal, institutional, behavioral and value changes as well as different trade-offs that occur in these various complex contexts.

4.2 Several contributions to this special section highlight that understanding and dealing with pandemics, e.g., COVID-19, requires attention to human values. This is the core idea of the article by Shults et al. (2024), which suggests that considering human values may be a crucial aspect of real-world pandemic management and is an important focus point in simulation modelling applied within public health domain. The authors present a model of value-based decision-support systems, emphasising the varying degrees of relevance that values have in guiding pandemic management. The article argues that values drive compliance decisions within populations and are, therefore, important factors to consider in pandemic management. The authors build their model upon an existing validated agent-based model, expanding it to incorporate human values and measuring the impact of activating or deactivating these values. They conclude with an invitation to explore their theoretical insights in practice.

4.3 Building upon a similar theoretical grounding, Czupryna et al. (2024) focus on developing an analogy model to explore how human values may influence aggregated economic performance and societal behaviour. The study highlights the role of values in cultural context across diverse societies and their importance in shaping

economic activities, societal interactions, and the overall output of a society. Researchers examine the impact of Schwartz's theory of universal human values on a society's collective output, considering dimensions such as public goods, private goods, and leisure time. Their study demonstrates that since values are guiding principles that drive decision-making and influence behaviour, they are subject to trade-offs that impact these dimensions. By studying the relationships between values and economic behaviour at the macro level, this contribution aims to provide insights into the gap between individual values and collective outcomes and the significant role of values in shaping individual and collective behaviour.

4.4 Following a psychological perspective on values, Ale Ebrahim Dehkordi et al. (2024) examine the relationship between changes in values and institutional responses during the COVID-19 pandemic, combining agent-based modelling and machine learning techniques to illustrate the role of values in institutional emergence. The authors' theoretical perspective on values utilises Schwartz's theory of universal human values and conceptualises values as deeply rooted motivations, significantly influencing individual decision-making on the state level and guiding institutional responses. This contribution studies the interplay between state level individual behaviour, values, and social structures during the pandemic, contributing insights for adaptive policies that align with societal values and enhance institutional effectiveness. The authors investigate how the COVID-19 pandemic has affected societal well-being and how institutions have responded to the crisis by exploring the correlations between changes in values and adaptive institutional responses. Despite similar types of institutional responses to the COVID-19 outbreak worldwide, this contribution explores the differences in the frequency and nature of changes by independently modelling value change and institutional change processes and exploring whether a change in values has driven institutional change during the crisis and to what extent.

4.5 Other challenges that societies face today are related to rapid technological development. de Wildt & van de Poel (2024) propose an exploratory agent-based model based on a pragmatist account of values, mainly drawing from Dewey's philosophical work on values and valuing, to delve into the question of how technological advancements and societal changes affect values. It argues that formal simulation models can help to better explore philosophical theories of value and value change and to understand the explanatory power of such accounts. To that end, the paper focuses on four critical phenomena related to value change and technologies: the inevitability and stability of values, differences in openness and resistance to value change between societies, moral revolutions, and lock-in. A theoretical exploration model is built to simulate potential value change in a society in response to moral problems caused by technologies, which are themselves partly the result of values in that society. The study is significant because it contributes to the application of agent-based modelling in the ethics of technology and aims to enrich the philosophical literature by formalising the relationship between technology, society, and values.

4.6 The questions concerning technologies and values are also gaining momentum in opinion dynamic modelling. Weinans et al. (2024) introduce an opinion dynamic model that includes values and discusses the significance of collective technology adoption in addressing challenges like climate change and pandemics. This contribution highlights that success in addressing such challenges depends on technological development and people's willingness to adopt these technologies, citing examples like vaccine acceptance during the COVID-19 pandemic and food choices after the EAT-Lancet report. The authors deploy machine learning techniques to explore the opinion-forming process, aiming to understand how opinions and values co-evolve in a community and how values are interconnected to social norms. This study takes a broad perspective on "values" that represent individuals' stable predispositions, including interests, occupation, party membership, and religion. The theory exploration model of drivers of opinion dynamics, proposed by the authors, focuses on how values influence the opinion-forming process and how individuals continuously adapt their opinions based on new information and their values. The article highlights the significance of exploring a co-evolution of values and norms in opinion dynamics models.

4.7 A less theoretically explicit but more problem-driven perspective is proposed by Davis et al. (2024) who explore the impact of diet on health and the food system's sustainability, focusing on the factors influencing dietary choices, including personal values, norms, social interactions, and habits. The values individuals attach to aspects like price, taste, ethics, and health are explored in this article, along with their impact on dietary decisions, which can sometimes be conflicting. The authors acknowledge trade-offs, considering factors like accessibility and affordability, and discuss the 'attitude-behavior gap,' where pro-environmental attitudes may not align with actual consumption patterns. The authors demonstrate that understanding public values is crucial in addressing the complexities of food choices, especially when focusing on larger-scale dietary changes. Despite the underutilisation of ABMs in this context, the authors aim to fill the gap by developing a model illustrating the causes of the attitude-behaviour gap around sustainable consumption. This contribution also explores the connection between values and social norms and examines their role in shaping dietary choices and individuals' self-categorisation based on personal and social identities. As an outcome, the authors identify ways to

overcome barriers and promote more sustainable food consumption patterns at the broader dietary scale, informing policy-making for healthier, sustainable, and affordable diets.

4.8 Jager et al. (2024) simulation model studies how values and norms coordinate human behaviour within social groups in the broader social innovation context and explores the potential impact of different scenarios of policies on social dynamics. Their contribution emphasises the importance of understanding the role of norms and values in local social innovation projects to address the complexities of changing behaviours related to energy use and other environmentally relevant practices while focusing on the emergence of normative institutions to protect shared systems. This contribution highlights the importance of values and norms in community-wide behavioural change and the concept of a "tipping point" where a critical mass of adopters can shift societal norms. While norms seem to facilitate coordination, the authors recognise their potential to impede innovation by promoting conformity. The authors illuminate the link between norms and personal value in three case studies to explore these dynamics. In their conclusion, the authors suggest that the operation of norms can only be understood in the context of other factors and drivers. They propose an integrated modelling framework HUMAT that includes values and needs to explore further the impact of social influence on norms and value changes in society.

4.9 Value preferences and other value-related concepts like social norms increasingly attract attention in policy-relevant modelling. The contribution by Madsen et al. (2024) proposes a social-ecological behavioural model to understand human adaptation to environmental changes in the context of fisheries management. The proposed model considers the weight of value preferences of fishermen and social norms in decision-making, recognising that fisher agents' choices are influenced by norms that vary between regions or contexts. The authors argue that understanding and incorporating value preferences and social norms into the model is crucial for accurately predicting and managing human behaviour in complex human-environmental systems. While the authors primarily focus on the role of social norms, the paper suggests that the proposed behavioural model considers financial, cultural, reputational, and legal values and, consequently, value preferences. The authors offer concrete and testable predictions and designed their model as part of the POSEIDON model for evaluating interventions in fisheries management. They emphasise that such a granularity that can be achieved by incorporating notions like value preferences and social norms enhances the model's adaptive nature and impacts its potential for informing policies to manage fisheries and other human-environmental systems.

4.10 While some of these papers explore how values shape decision-making, behaviour, and actions on individual levels, others demonstrate technologically induced value changes and opinion dynamics on collective levels. Some contributions may be more speculative with a view to generating testable hypotheses or simply based on common-sense (what psychologists call "folk theory"), where relatively few approaches to modelling values take a more data-driven approach to specifying the value processes in models or in their parameters. Such a broad range of perspectives, as well as the distinguishable theoretically or empirically driven nature of these perspectives, demonstrates a lot of room in continuing the path of modelling values (see Table 1).

Discussions and Future Research

5.1 In this special section editorial, we introduced interdisciplinary perspectives on values to reflect on growing appeals for modelling values and stimulate interest in the development of ontological, methodological, and epistemological approaches that study and operationalise values in ABMs.

5.2 Contributions to this special section illustrate the variety of value conceptualisations, operationalisations and formalisations in theoretically and empirically driven ABMs and their role in exploring the complex problems raised in social, socio-technical and socio-ecological systems. While some perspectives on values prevailed, more research into modelling values based on anthropological, sociological and philosophical accounts is needed to enrich theoretical and empirical applications of ABMs and reflect on these applications more systematically. Future trajectories for follow-up research on modelling values include different modelling domains like institutional, socio-ecological, socio-technical, and socio-cognitive modelling.

5.3 For institutional modelling, values can provide a theoretical ground for exploring institutional emergence and changes in social structures, particularly relevant in times of technological disruption and crises. Additional perspectives on values, particularly empirical ones, can improve institutional modelling robustness through validation and sensitivity analysis.

5.4 In socio-technical system modelling, different value perspectives can allow researchers to scale up their understanding of technologies as not merely instrumental model components but embedding specific values that

may induce societal change. More research involving different perspectives on values can contribute to exploring the diffusion of innovation and the effectiveness of climate and energy-related policies.

5.5 In the socio-ecological context, modelling value can be relevant for understanding the role of environmental concerns in decision-making to provide policymakers with insight and robust conceptualisation of notions like e.g., resilience to improve the existing practices of measuring such qualitative concepts.

5.6 For socio-cognitive modelling, insights into theoretically and empirically driven accounts of values may allow a finer granularity regarding the diversity of agents' cognitive architectures and, consequently, a richer exploration of the impact of such diversities in decision-making and behaviour patterns. Improvement in agents' cognitive architectures may allow researchers to come closer to transcending the "old school" rational agency paradigm originating from economics and move closer to making simulation modelling and agent-based models that useful for policy exploration.

5.7 Attempts to transcend the rational agency paradigm have long occurred in political science research, particularly on opinion dynamics where political, social, and moral values, among other things, are at the root of disagreements. Here, future research on the role of values in opinion dynamics may help better understand and navigate challenges related to polarisation and social controversies regarding new policies and technologies.

5.8 Also, a more elaborate reflection is needed on how different accounts in modelling values can correspond with modelling purposes (Edmonds, 2017). In the future, such a systematic exploration can be combined with insights into how theories in agent-based modelling are generally formalised. Antosz et al. (2023) explore various ways of using theories in ABMs and outline general patterns of theories used as input. Some of these patterns are relevant to how theories of values were used in contributions to this special section and are relevant for future research in modelling values. For instance, ABMs can be created to refine theory and make concrete realisations of different conceptual accounts of the impact and role of values. Alternatively, to demonstrate how one theory explains observed patterns whereas the other does not, which might allow the comparison of the impacts of different ways in which values could be important and thus aid in their evaluation as theories. Furthermore, it is possible to build several models collectively representing one theory so that a family of models could explore the space in which values are a significant factor as a stage towards the better and more comprehensive development of representations of the structures and processes involved.

5.9 Finally, but significantly, we urge future contributions to be explicit in their modelling assumptions, thereby establishing a robust foundation for scientific discourse. Instead of scientists beginning from scratch and articulating their perspectives on values, the works presented within this special section aim to foster discussion and collaboration among research groups. The goal is to build solid theoretical and empirical groundwork for future endeavours on modelling values.

Conclusion

6.1 Values are an important part of our individual and collective lives. Agent-based simulation is the only technique that formally captures the interaction between the micro- (individual) and macro- (societal) levels that we observe and thus can bring together the different aspects of values that are identified in other fields – to integrate them and allow the exploration of how these aspects might interact. Although, historically, other micro-macro phenomena (norms, rational weighing of choices, social influence of opinions, etc.) have been applied and explored within the social simulation to a greater extent, this special section in the Journal of Artificial Societies and Social Simulation shows that values are now getting increasing attention. Without including values, we will not be able to fully understand many of the crucial societal, technological, and environmental changes that face us (e.g., climate change, political reform, conflict resolution, etc.). It is thus vital that this area of research is now further developed with careful attention to modelling assumptions about values.

Funding

Appendix

TABLE 1: Classification of value perspectives and contexts used in the special section contributions.

Contribution	Context	Value Perspective	Value Theory	Level	Empirical data for values	Modelling Purpose
Shults et al. (2024)	Values COVID-19 pandemic management	Psychology	Schwartz et al. (2012)	Individual	x	Illustration
Czupryna et al. (2024)	Values in COVID-19 pandemic and economic performance	Psychology	Schwartz et al. (2012)	Individual	ESS, Behavioural experiments for calibration	Analogy
Ale Ebrahim Dehkordi et al. (2024)	Values in COVID-19 pandemic and institutional emergence	Psychology, and Ethics of Technology	Schwartz et al. (2012), van de Poel (2018)	Individual, aggregated to state level	ESS dataset for calibration	Illustration
de Wildt & van de Poel (2024)	Technological development and value change	Philosophy, and Ethics of Technology	Dewey's account of values and value change	Collective	x	Theoretical Exploration
Weinans et al. (2024)	Opinion dynamics and value change	Psychological origin	Zaller (1991)	Individual	x	Theoretical Exploration
Davis et al. (2024)	Dietary changes and relations between values and norms	Psychology	x	Individual	ESS for calibration	Illustration
Jager et al. (2024)	Values and norms in local communities	Psychology	Schwartz et al. (2012)	Collective & Individual	Interviews	Theoretical Exploration
Madsen et al. (2024)	Value preferences in socio-ecological modelling	Psychology	x	Individual	x	Illustration

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