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Behavioural issues in environmental modelling - the missing perspective

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Abstract

The paper aims to demonstrate the importance of behavioural issues in environmental modelling. These issues can relate both to the modeler and to the modelling process including the social interaction in the modelling team. The origins of behavioural effects can be in the cognitive and motivational biases or in the social systems created as well as in the visual and verbal communication strategies used. The possible occurrence of these phenomena in the context of environmental modelling is discussed and suggestions for research topics are provided.

Keywords: Behavioural effects, Cognitive biases, Best practice, Modeler Bias, Communication, Systems intelligence

Highlights

- Behavioural effects of the modeler and the modelling process need to be studied
- Cognitive, motivational and social biases and communication effects are important
- Modelers are also subject to other biases which must be considered
- Modelers should recognize the possibility of strategic behavior of the participants
- Modeler in the of problem solving system and must act with systems intelligence

1. Introduction

Every environmental model embeds behavioural issues related to the modeler. Modelling is not about models only. It matters how we choose the models and how we work with the models. In a recent paper (Hämäläinen et al., 2013) we introduced the term Behavioural Operational Research (BOR). It refers to research which considers the human impact on the process of using operational research (OR) methods in problem solving and decision support as well as using OR methods to model human behavior. We pointed out the need to take into account effects caused by mental models and cognitive biases as well as social systems created and communication effects. In participatory problem solving and decision making the way the interaction and communication is carried out becomes important and has an effect on the dynamics of the problem solving process. This can influence the behavior and preferences of the participants (see e.g. Slotte and Hämäläinen, 2015). For the modeler it is useful to view such social processes as systems in which she is an active player (see e.g., Hämäläinen and Saarinen 2008 and Luoma et.al. 2011).

The aim of this paper is to bring behavioural issues and perspective into the discourse taking place in the environmental modelling community too. Because of the complexities of the problems in environmental management the focus is easily narrowed down to seeking the best model only. Listing different types of modelling approaches and their technical merits and weaknesses is not enough as it can leave us ignorant of the problems and risks related to the way the models are used and implemented. For example, the recent position paper by Kelly et al. (2013) has a very extensive discussion of modelling approaches but does not consider the modeler risks in these approaches. There are many studies related to uncertainties in environmental modelling and impact assessment (for a review see, e.g., Refsgaard, 2007). There is also literature on uncertainties due to model structure error (Refsgaard et al., 2006) but very few studies on the uncertainties related to the skills and behavior of the modeler. The review of Matott et al. (2009) includes a note on Wheeler effects which refers to the difficulty of recognizing one's incompetence (Kruger and Dunning, 1999). Linkov and Burmistrov (2003) consider explicitly modeler bias and the role of expert opinions. The literature on expert judgment is also important as it considers ways to use expert opinion in modelling. This topic has been discussed in connection with environmental modelling by Krueger et al. 2012 and Blake, 2014. The rapid increase of the use of multicriteria modelling in environmental decision making (see, e.g., Herath and Prato, 2006; Linkov and Moberg, 2012) has helped to deal with the values and goals of the participants. One of the main reasons for using MCDA methods in group processes is that the participants' values can be dealt with in a transparent way (Salo and Hämäläinen, 2010). However, the question how values are related to behavioural issues in model use has not received much attention. Values can also be the drivers in motivational biases.

This paper introduces behavioural phenomena which can be relevant in the practice of modelling. There is very little research on the modelling of the modeler or on modeling the effects of these phenomena. How to avoid these behavioural effects, e.g., by debiasing is an open research question. This is a very interesting but difficult theme discussed so far only to some extent in the area of decision analysis (see, e.g., Lahtinen and Hämäläinen, 2015; Montibeller and v. Winterfeldt, 2015).

The need and interest to consider behavioural effects and biases has been recognized in other disciplines when their theoretical core has matured enough. Such examples are economics, game theory and finance. In these areas the original theoretical models and results were based on idealized assumptions about human behaviour, e.g., profit maximization, which are not always followed in the real behaviour of people. Today there is strong interest in analyzing economic decision making experimentally. Understanding the reasons for the choice behaviours observed has become the focus of research. The questions of interest include, for example, are people self-regarding or other regarding and what explains investor behaviour which does not reflect expected utility maximization. The introduction of more realistic assumptions about peoples' "behaviour aims to better theoretical insights and predictions for better policies" (Camerer and Loewenstein, 2004). The discussion of behavioural effects has also reached environmental economics (Shogren and Taylor, 2008). Environmental modelling is a mature field too and it is now natural to pay more attention to behavioural effects. The main goal of considering behavioural issues more carefully in environmental modelling is also to improve the understanding of decision processes and to produce better predictions, decisions and policies. The importance of modelling in helping to understand and manage environmental problems is widely accepted. Models are being used in an ever increasing pace and in the crucial problems of mankind. But how often do we ask about the possible behavioural issues and problems in the process of generating and using the models? There are best practice guidelines but we need more understanding about how and what can go wrong due to behavioural issues originating from the modeler, participants or the system of problem solving created.

2. Modelling

The book Limits to Growth by Meadows et al. published already in 1972 is among the pioneering work in the field of environmental policy modelling. The authors worked in the

MIT Systems Dynamics Community which had understood the risks in modelling (Sterman, 1991, 2002). However, it seems that the widespread use of modelling has left these issues with less attention. Environmental researchers often have their background in the natural sciences. This easily anchors us, or at least the novice modeler, with the idea that models are true and accurate descriptions of the reality even if models are sometimes also used only to give structure to the phenomena studied (Hämäläinen et al., 2014). Accuracy of description is naturally the goal when we aim to explain phenomena and characterize environmental systems. However, when models are developed to manage or solve problems the issue of validity becomes a different question. The purpose for which the model is developed is reflected in the parameters and scales as well as in the level of detail used. John Sterman (2002) used the phrase “All models are wrong” in the title of his famous paper in which he emphasizes the balance of assumptions with the intended use of the model. The phrase had already earlier been used in the context of statistical modeling (Box, 1976) when emphasizing the interplay of practice and model development. The main message of Sterman is that model boundaries and the level of detail used in the description depend on the intended use of the model. There is not a single valid model fitting every purpose. Today, these principles are indeed emphasized in the field of environmental modelling too (Jakeman et al., 2006; Harmel et al., 2014). This naturally leads to ask the question how well do we modellers succeed in matching the model with its intended purpose.

In considering the behavioural effects we should take a humble approach and accept the fact that we are not likely be able to produce a “perfect” model but still could find one that is useful. Sometimes the usefulness of a model is not about accuracy (Bennett et al., 2013) but it can also be evaluated, for example, by taking into account the learning acquired during the process of building the model both by the modelers and the problem owners (Jakeman et al., 2006; Senge et al., 2008). Learning and improved communication are often reported to be the most important benefits especially in participatory multicriteria and system dynamics approaches (van den Belt, 2004). In these situations, the modeler behaviour in the interaction becomes important. The modeler should not only be focused on the perfection of the accuracy of the model, but the process and communication counts a lot too (Marx et al., 2007). It would be preferable to use models in a facilitated mode rather than in an expert mode (Franco and Montibeller, 2010).Today, there is increasing interest in understanding peoples' ways of thinking and deciding in different settings. We are suggested to have two ways of thinking, fast and slow or system 1 and system 2 (for a discussion see Kahneman, 2011). How is this reflected in the participative decision making proce? For us modelers this can also be of interest. When is fast or slow reasoning process the desired one and can the use of models help in stimulating either one?

Best practice papers like the one by Black et al. (2014) focus on the process and acknowledge that a valid model can be used in different ways. Thus the human behavioural impact is indeed recognized. So far, we have very few comparative analyses of the pros and cons of alternative best practices (for some examples see French et al., 1998; Brocklesby, 2009; Marttunen et al., 2015). There are no meta-level analyses how different modelers have succeeded in following the best practice guidelines. The implicit assumption in best practice approaches seems to be that model users are good willed and able to avoid psychological biases in their own practice. The idea of the existence of one ideal process can still prevail. The modelers need to acknowledge the fact that different modeling processes can lead to different outcomes. For a discussion of path dependence in modelling and the related drivers see Hämäläinen and Lahtinen, 2015. Behavioural issues are also closely related to ethical issues. Ethics in modelling has been discussed extensively in the OR literature (Wallace, 1994; Rauschmayer, 2001; Gass, 2009; Walker, 2009; Ormerod and Ulrich, 2013). It is noteworthy that most of these discussions provide guiding principles but few real cases are analyzed retrospectively (Brocklesby, 2009) and no experimental analyses of the success of following the guidelines are reported.

The discipline of Integrated Environmental Modelling (IEM) has an explicit aim to integrate transdisciplinarity into solving complex real world problems (Laniak et al., 2013). The field emphasizes that it is science based. Its idea is to use interdependent models components related to different aspects of the problem including the environment and human systems. In evaluating the IEM process (see, e.g., Schwanitz, 2013) the belief in the existence of an ideal correct model can remain when the science based characterization of EIM is emphasized. It is interesting to notice, however, that a paper by Glynn (2015) published after the review process of the current paper discusses the human dimension in IEM.

In model evaluation, the need to compare results by using alternative models is also noted in the literature (see, e.g., Refsgaard et al., 2006, 2007) and multimodelling has been endorsed, e.g., in water resources studies (Beven, 2006; Boomer et al., 2013). Multimodeling is an important issue in climate modelling. In this field it is of interest to produce an aggregated or averaged climate projection based on different models. The methods used for weighting the simulations have been largely subjective (for a discussion see Räisänen et al., 2010). Subjectivity means that such averaging procedures bring in behavioural effects into the solutions which originate from the modeler. It also means that the possibilities for transparent physical explanations of the results are reduced. The need to compare the usefulness of different models has been studied in general (Tako and Robinson, 2009) but clearly the topic needs more research in environmental contexts. The point that different modelers could come up with different results even when using the same modelling tools is not widely discussed. First steps in this topic are already taken in the important context of climate modelling (see, e.g., Räisänen and Ylhäisi, 2014).

3. Biases

Research in psychology has reported many types of cognitive and social biases as well as heuristics which relate to human behaviour (see, e.g., Wikipedia, 2015; Gigerenzer and Todd, 1999; Pohl, 2004a). Biases related to decision making were described in the seminal works of Kahneman et al. (1982) and have already received attention in the environmental literature. Later extensive research has taken place in the decision analysis literature. We do know that biases exist but it is not at all easy to find ways to avoid them (see, e.g., Pöyhönen and Hämäläinen, 2000; Hämäläinen and Alaja, 2008). Montibeller and von Winterfeldt (2015) provide a comprehensive list of cognitive and motivational biases in decision making with a

Table 1. Typical biases in decision making, preference elicitation and expert opinions as well as possibilities for debiasing. Table is a partial and condensed version of the original one presented in Montibeller and v. Winterfeldt (2015).

Bias	Explanation	Debiasing
Anchoring	A numerical value is based on an initial value (anchor), which is then insufficiently adjusted to provide the final answer.	Avoid anchors. Use different experts who use different anchors.
Certainty effect	People prefer sure things to gambles with similar expected utilities.	Separate value and utility elicitation.
Equalizing bias	Decision makers allocate similar weights to all objectives or similar probabilities to all events.	Elicit weights or probabilities hierarchically.
Gain-loss bias	Descriptions of a choice and its outcomes either as gains or as losses and may lead to different answers.	Clearly identify the *status quo* .
Myopic problem representation	Oversimplified problem representation is adopted based on an incomplete mental model of the decision problem.	Explicitly encourage to think about more objectives, new alternatives.
Splitting biases	The way the objectives are grouped in a value tree affects their weights or the way a fault tree is pruned affects the	Use hierarchical estimation of weights or probabilities.
Proxy bias	Proxy attributes receive larger weights than the respective fundamental objectives.	Avoid proxy attributes.
Range insensitivity bias	Weights of objectives are not properly adjusted to changes in the range of attributes.	Make attribute ranges explicit. Use multiple elicitation procedures.
Scaling	Underestimating large sizes/differences and overestimating small/sizes differences.	Choose appropriate scaling techniques.

discussion of related debiasing technique (see Table 1). For more details the interested reader should consult the original paper and also note the review on biases in resource allocation and portfolio decision analysis by Fasolo et al. (2011). Many environmental decisions are, in fact, portfolio problems. Research on environmental valuation also faces big challenges in trying to mitigate biases (see, e.g., List, 2001; Harrison, 2006). Cognitive biases in decision making are related to the decision makers' judgments but also to the way the decision problems are framed. Modelers are also subject to a number of other cognitive biases the effects of which have not been much studied. These include, e.g.:

- Man and Hammer also called the Hammer and Nail syndrome: If all you have is a hammer, everything looks like a nail. A modeler can be knowledgeable of a single modelling tool and sees every problem to be solvable with that tool. This issue is has been raised in the environmental modelling literature, e.g., by Voinov (2008) and Voinov and Bousquet (2010).

- Confirmation bias: We interpret data and evidence or use models to support or confirm the validity of our assumptions and desired results. Environmental modelling is often related to strongly value laden issues and this can challenge the neutrality of the modeler and create the confirmation bias if the modeler has strong opinion of the issue being modelled.
- Cognitive dissonance: We can simultaneously try to believe in two incompatible things – the model and the reality. A modeler can be eager to use his/her special favored modeling approach so that the real validity of the model is not challenged. Modelers can in general be overly eager to show the benefits of modeling and make compromises in the model testing.
- Appeal to authority: We can uncritically try to follow those modelling traditions which are regarded as being in positions of authority. We can be less critical of the models developed by established organizations.
- Loss-aversion: We can do stupid things to avoid the realization of a loss. Loss aversion in modeling is a real risk as it can be difficult to acknowledge the failure or unsuccessfulness of our modelling approach in particular with large complex models with lots of work put into developing them. This can lead to working too long trying to improve an unsuitable model or a model for which reliable parameters are not easily available.

Motivational biases that can influence the quality of modelling by distorting the parameter elicitation and expert judgments. The cumulative effects of biases in a modelling process can also result in path dependency (Lahtinen and Hämäläinen, 2015). This refers to a phenomenon where the order in which steps are taken in the modelling process can have an impact on the resulting model. In large environmental models the initial modeling choices can be very hard to change later and these can have a crucial impact on the path the modeling process will proceed. The loss aversion effect in decision making (Kahneman and Tversky, 1984) can also have an effect on modelling in general. Theoretically it can be equivalent to use and label variables as losses or gains but in the interpretation of the model results there can be a difference (see Pohl, 2004b for a discussion of the labeling effect). A somewhat related effect is the so called action bias where people choose to foster improvement rather than prevent deterioration (Patt and Zeckhauser, 2000).

Groupthink (Janis, 1972) is a psychological phenomenon which can occur, for example, in highly trained cohesive groups. In such an environment, the group members can refrain from critical thinking and from raising controversial perspectives. This can lead the group to unquestioned beliefs in the decisions it makes. In modelling there can be a risk of groupthink in cohesive communities of researchers dedicated to a particular modelling approach.

A notable example of narrowing to one's own professional traditions and tools is that the modelling approaches for environmental valuation used by economists usually exclude multicriteria models (Gregory et al., 1993; Gregory et al., 2012) even though these models are widely used in practice. A possible reflection of groupthink is the fact that the environmental LCA community had developed weighting methods in their own forums without being aware of the work done earlier in the field of decision analysis (Miettinen and Hämäläinen, 1997, 1999; Seppälä and Hämäläinen, 2001). Also communities of best practice, which do exist for example in the area of integrated environmental modelling (Laniak et al., 2013), can face the risk of groupthink. It would be interesting to study the risks of groupthink and biases in processes which have a strong social component and are used in environmental modelling processes. These include participatory modelling (Voinov and Bousquet, 2010), interactive preference elicitation (Marttunen and Hämäläinen, 2008), decision conferences (Mustajoki et al., 2007; Phillips and Bana e Costa, 2007; Slotte and Hämäläinen, 2015) and role playing games (e.g., Souchère et al., 2010). Research on groupthink is difficult as one cannot repeat group processes with the real decision makers. The approaches taken to study groupthink in general settings include retrospective analyses of the existence of the antecedents and symptoms of groupthink (Esser, 1998). The literature on groupthink in environmental modeling is very limited even if the risk was identified already early on in environmental policy making see, e.g., by Kennedy (1988) and the phenomenon is today discussed in guides on environmental decision making with multicriteria approaches (Gregory et al., 2012). A natural idea to lower the risk of groupthink is to use peer review of the process and multimodeling. One could also consider analyzing the mental models of the participants (see Wood et al., 2012). To avoid groupthink by repeating problem solving processes based on different approaches can, however, be impossible in practice. For the practitioner groupthink is a phenomenon to be kept in mind and the risk of which can be mitigated by a serious open questioning and challenging of the approaches and actions of the participants in the modeling process.

In general there are possible problems related to biases when using a single agency to do modelling in environmental management problems. A consulting firm or a team in a research agency can be specialized in one modelling technique. This can create the risk of the Man and the Hammer syndrome as well as hide other biases if there is not transparency or close follow up of the process. Budgetary constraints and the profit seeking behaviour of the modeling agency can also contribute to the limited scope of models considered. The need for more transparency has been voiced frequently (see, e.g., Alexandrov et al., 2011) but the issue of modeler biases has not been raised. Ways to identify these risks include peer review which would be a very good way to evaluate models. It is not, however, widely used perhaps due to time and cost limitations. There are clearly also research opportunities in evaluating different ways of carrying out peer reviews of models.

4. Communication

Communication is an important part of modelling. The way the data is shown and discussed can have strong behavioural consequences in environmental contexts in particular where stakeholders can have very different cultural and educational backgrounds. There is extensive literature on risk communication but still the challenge to find ways to avoid misunderstandings in communicating uncertainty remains. All of this is naturally relevant in environmental modelling research as well (Patt and Dessai, 2005). Misunderstandings of phenomena do not need to reflect people's lack of cognitive abilities but the way the situation is described in the communication (Marx et al., 2007). A good example is the test where well-educated people did not understand simple dynamics (Cronin et al., 2009). The case was re-examined by Hämäläinen et al. (2013) with minor changes in the problem description and graphs and this lead to completely opposite results. In the original test the participants were shown a graph with two zig-zagging peaked curves representing the number of customers entering and leaving a department store. The questions in the test included simple ones as "During which minute did the most people enter/leave the store?" the answers to which could be seen from the peaks of the curves. Then there was a question "During which minute were the most people in the store?" This question was followed by a cannot be determined box as an alternative answer. There were only 44 per cent correct answers. In the modified test

(Hämäläinen et al. 2013) the curves were less peaked and there were additional questions related to the accumulation phenomena directly. This changed the results completely and there were about 90 per cent correct answers. The conclusion is that the reason for the lack of correct answers in the original test was the false cues originating from the shape of the curves. They could trigger impropriate solution heuristics to focus on the peaks. Also the “cannot be determined“ box primed to think that the task was very difficult.

There is also another paper by Sterman and Sweeney (2007) with a somewhat similar test on the stock and flow effects related to atmospheric CO_2. Again the result was that peoples’ thinking violates the principle of mass-balance. This is an interesting case because this conclusion that people do not understand simple dynamics is used as an explanation why people do not understand climate change (see, e.g., Sterman, 2008). These papers raise questions about the origins and validity of the results. Is it really true that people do not understand stock-and-flow dynamics and would need interactive simulators for help as suggested by Sterman and Sweeney (2007), see also Sterman et al. (2013). One could claim that most mothers who buy milk for their children do understand the simple stock and flow accumulation dynamics and mass-balance in the system related to the amount of milk in their refrigerator. Mothers learns to estimate the dynamics of consumption and know how often new milk needs to be purchased. So the problems are likely to arise elsewhere and most likely to be related to the complexity of the context and perhaps to the value ladedness of the issues considered (see, e.g., Moser, 2010). There is interesting related research going on in environmental education on how to help people understand climate dynamics by using simple metaphorical visualizations (Niebert and Gropengiesser, 2013). So, for us the general conclusion is that model related communication should be high on the agenda in behavioural research in modelling.

Using and working with models interactively over the internet is likely to increase in the future. There will be new challenges in the ways models are described and explained to the users over the internet. Clearly this new communication environment can raise new behavioural effects to be studied. Also the new social media are likely to be used increasingly in stakeholder participation related to environmental management (for a review of the related risks in general see Picazo-Vela et al., 2012). Behavioural issues will become most relevant when social media will be used in participatory modelling, for example, for the elicitation of preferences or social impacts. There is already growing interest in using decision models in e-participation (see, e.g., Hämäläinen, 2003; Mustajoki et al., 2004; French et al., 2007; Hämäläinen et al., 2010). Data from social media is recently used in models of the formation of opinions (see, e.g., Sobkowicz et al., 2012). It also been shown that emotions do play a role in model based e-negotiations (Hine et al., 2009) The natural next step is to use agent based models to simulate and direct peoples' opinions. An example is the work by Mosler and Martens (2008) on changing environmental attitudes by agent-based simulators. Clearly this kind of modelling research brings with it ethical questions about the acceptable ways how people's behaviour can be influenced or manipulated.

5. Strategic behaviour

Human cognitive processes relate strongly to motivational issues which interplay between people in social contexts. The recent review by Fraternali et al. (2012) on human computing lists many points which should also be considered in more traditional modelling approaches. Self-interest is usually the driver in strategic behavior. Modelers should recognize the possibility of strategic behavior of the participants. Such behavior can mean, for example, the misrepresentation of preferences or data in an environmental participation process.

A phenomenon called strategy bias has received attention in the managerial literature (see, e.g., Bukszar, 1999; Barnes, 1984). The term refers to misunderstandings and misinterpretations of data when making strategic decisions. These phenomenona are likely to take place in environmental decision making as well. Huesemann (2002) describes three types of biases in public policy: personal, institutional and socio-cultural. These biases refer to self-interest as a driver of behavior. For example, an individual can try to gain personal advantage from research and organizations can focus on work that produces favorable results for their interests. Huesemann (2002) concludes that self-interest is the primary cause of biases in environmental research in particular in participatory processes with multiple stakeholders. People are also generally assumed to be driven by self-interest. People optimize their consumption using benefit cost rationality and this price elasticity is used, for example, when designing regulatory measures by environmental taxes. The paper by Hajkowicz (2012) is the first one to test the presence of strategic bias in an environmental negotiation case which was about the allocation of funds to different regions. He observed moderate strategic bias in the form that regions selected weights in the MCDM approach so that the result would improve their own regions outcome.

Misrepresentation of values can also be a way of making an alternative look better in the eyes of the general public. For example, in many countries nuclear power divides opinions so that greens do not support it but conservatives do. In Finland, we had a debate in the parliament on the nuclear power plant license and in this debate an MCDA model was used publicly (see Hämäläinen, 1990, 1991). In such a situation, a politician can state her preferences so that it seems that one thinks highly of environmental values and can end up either supporting or not supporting the nuclear option. So, in theory a politician can intentionally use MCDA to change the image of her motives. This raises the natural and interesting question if modelling can and if it has been used in greenwashing either in the political or corporate world. An American comedian Stephen Colbert has recently coined the term truthiness which refers to a phenomenon where people's judgements are affected by a nonprobative information even if it is present only for a short period of time (see, e.g., Newman et al., 2012; Fenn et al., 2013). This can possibly also occur in modelling contexts. Showing alternative graphs of modelling results or expected outcomes can make a difference.

"Cheap talk" refers to a special kind of strategic communication. It is an announcement which is costless to the sender and the signal is provided before a decision or choice is made by the receiver. Cheap talk can be found in different contexts. In game settings the signal can influence the mode of play of the receiver. Economists have been interested in the reasons for using cheap talk (see, e.g., Farrell and Rabin, 1996). Experimental game research has suggested that people use cheap talk for collaborative purposes to reach mutual benefits (Crawford 1998; Leppänen and Hämäläinen, 2014). A very general related policy question is how often are models used as cheap talk signals. For non-experts mathematical models in general can represent tested and reliable sources of information. So if one justifies decisions by referring to the results of a model without explaining its assumptions and limitations this can be strategic cheap talk. In the context of willingness to pay studies in environmental evaluation research the term cheap talk refers to advance information given to the respondents, e.g., about the risks of response biases (see, e.g., Ami et al., 2011). Such cheap talk has been shown to have an influence on the results. One could also considered corporate greenwashing (see, e.g., Delmas and Burbano, 2011) as cheap talk type strategic communication. In participatory modelling stakeholders and interest groups can also have possibilities to use cheap talk both to influence decisions of the other stakeholders as well as to influence the choices made by modelers about the related model framing and system boundaries.

In environmental problems, we have multiple stakeholders with different goals and values. In such a setting motivational effects and biases as well as strategic behavior are natural to appear. A modeler as well as the experts used to support model building can be tempted to overemphasize the possibilities of the occurrence of some undesired environmental impacts. A problem owner or a stakeholder being responsible for causing an undesired impact on nature can commission or direct modelers to look into the positive more desirable effects in more detail and thus change the perception of the overall impacts. Motivational biases and strategic behaviour can be hidden in the assumptions used in problem framing and definition of the system boundaries (Kloprogga et al., 2011). This kind of challenges brings the question of the ethics of modelling onto the table (see, e.g., Brocklesby, 2009; Ormerod and Ulrich, 2013).

6. The systems perspective

Environmental modelling is about studying and explaining systems (Voinov, 2008). It is also about working with and within systems (Senge et al., 2008). The systems perspective has been recognized as important when working with environmental conflicts see, e.g., the excellent text by Daniels and Walker (2001). The authors also relate systems thinking to collaborative learning but they do not explicitly consider the role of modelling. Even if their discussion is presented in the conflict management setting it relates directly to other problem solving situations and modelling too. When a modeler starts his work she is already a part of the social system herself. It is created by all the people involved in the problem solving with their intrinsic mental models, intentions, expectations and cultural habits. The macro-cognition of teams is a systemic phenomenon also present when modeling with stakeholders (Fiore at al., 2010; Cooke et al., 2013). The overall system in a modeling case can include actors like the stakeholders, experts and authorities. The challenge of the modeler is to act intelligently within this overall complex including both the environmental system under study and the organization of the social problem solving system. Communication patterns influence and create systems. It is important to recognize strategic and motivational goals in communication taking place. It is important to think if they are or should be part of the models used. It is known that emotions play an essential role when people evaluate and make decisions (Damasio, 1994). Emotions are contagious and influence group behaviour. Emotions can also be used strategically in negotiations (Kopelman et al., 2006). Positivity increases openness and broadens thinking (Fredrickson, 2001). This means that emotions are seemingly invisible actors in the system of problem solving. A skillful modeler and facilitator is sensitive to these issues when navigating the modelling process. The multifaceted participation process needs to be managed by the team where the modeler typically has a key role. The systemic behavioural elements in problem solving and learning discussed by Argyris (1982) are most relevant also in model based problem solving. Understanding these behavioural challenges is also a key modelling competence. The environment is a fundamental factor affecting our life and changes in it have systemic impacts which also reach our personal feelings and wellbeing. These systems aspects are beautifully described by Peter Senge (2014) in his talk entitled “Systems Thinking for a Better World”. To find improvements it is not enough to describe our environment as a system but to learn to act from within the overall system of problem solving. The modeler needs to widen his skill set from systems thinking to systems intelligence (Saarinen and Hämäläinen, 2004; Hämäläinen and Saarinen, 2008; Luoma et al., 2011). Systems intelligence refers to our ability to act intelligently and productively in systemic settings and to see the interconnections and leverage points in the system. The competence of systems intelligence consists of eight main factors (Hämäläinen et al., 2014): Systemic Perception, Attunement, Reflection, Positive Engagement, Spirited Discovery, Effective Responsiveness, Wise Action and Positive Attitude. Without going into the details the factor names already give an idea of the relevance of these competenses in participatory processes. When the modeler takes a systems intelligence lens she develops both the model as well as the process by which she engages with the stakeholders and problem owners.

7. Adopting the behavioural lens

The previous sections have illustrated a rich set of phenomena that relate to behavioural issues in environmental modelling. The natural question to ask is: Do we need a general framework to guide our work in this field. I think the behavioural lens needs to be integrated into all the processes in modelling as an additional perspective. One way to do this would be to consider all the modelling steps that the modeler is typically following and go through them with the question: What behavioural effects could be related to each step and are they likely to be important and is there something that could be done to avoid undesired behavioural effects. Such a behavioural check list screening is likely to be useful and improve the trustworthiness of the modelling process.

Different types of topic classifications can yet be developed. On a general level one could want to summarize ideas how to avoid problems caused by behaviour effects and identify open research questions. Table 2 provides one illustrative classification the origins of behavioural issues and lists some research themes and possible ways to meet the challenges in practice.

The kind of research that is needed when studying behavioural effects is typically experimental. This creates challenges when dealing with real problems. You cannot easily use real stakeholders as test subjects. However, there can still be situations where the problem

Table 2. An illustrative list of sources of behavioural phenomena in environmental modeling, availability of related research literature, research needs and ideas of practical measures to be take into account and considered.

Sources of behavioural phenomena	General research literature	Research literature in environmental modelling	Examples of research topics in environmental modeling	Ideas of things we can do in practice
Modeler				
Professional skills in modelling, facilitation, communication and following best practices.	Very limited, modelling guidelines only.	Best practices and guidelines only. No experimental or comprative studies.	How to identify lack of professionalism. Comparative studies of best practices. Experiments with different modelers. Does modeler's gender affect the selection and use of modeling approaches. The emergence and prevalence of modeler biases. Which modelling tasks are most prone to modeler biases.	Peer review of modeling processes. Use more than one modeler. Beware of the Hammer and Nail syndrome. Certification of modelers. Raising awareness of the possibilities of modeler biases and the importance of ethics.
Stakeholders and experts				
Judgmental and cognitive biases	Extensive literature related to decision making but very limited on debiasing methods. Expert judgment and forecasting.	Very limited	Biases related to expert judgement in environmental modelling. Effects of the selection variables and scales. Methods for debiasing in experts' judgement and decision making. The effects of mental models and framing.	Discuss biases and try to help the participants in understanding and avoiding them. Discuss the problem framing and the mental models of the participants. Frame problems so that biases are less likely to appear. Use alternative approaches in parallel.
Valuation and elicitation of preferences	Extensive in decision analysis and in cost-benefit analysis.	Extensive in environmental valuation but limited in MCDM modelling.	How to improve and avoid biases in multi-attribute evaluation? How to avoid biases in structuring. Which elicitation methods are less likely to produce biases.	Use transparent and least bias prone methods. Use more than one elicitation method. Consider ways of debiasing
Emotions	Extensive research on the role of emotions in decision making. Studies in environmental psychology.	None?	Role of emotions in model based participation. How does the modelling process trigger emotions? Are emotions a problem or can they contribute to the solution? The role of emotions in creating trust and learning with models. Effects of using positive or negative (losses/gains) impacts as variables.	Do not underestimate the role and impact of emotions in model use. Discuss and avoid enforcing modelling truths. Models can create fear and decrease trust. Present models in an enquiry mode rather than in an advocacy mode. Modelers should learn the basics of environmental psychology.
Communication				
Risk communication	Extensive	Risk models widely used in environmental problems but risks in modeling are not considered.	Do we understand model related risks? Do models introduce risks of false feelings of certainty.	Explain model related uncertainties and limitations of assumptions and sources of data.
Learning with modelling	Limited	Very limited. Modelling is found to improve learning but there are no analyses why and how this happens.	Experiments on learning with modeling. What kind of models are the most useful ones for learning in different situations.	Use transparent and simplified models for learning and comprehensive models for problem solving. Use models interactively in a dialogue with the stakeholders. Evaluate learning by feedback questions.
Communicating with models	Limited	Limited	How to use models in communication. How to best describe model assumptions outputs and relationships. Gender and cultural issues. The impact of different visualizations.	Emphasize the assumptions, scope and limitations of the model. Use models interactively with the stakeholders. Consider carefully how to present the results. Evaluate by feedback if the model and results are understood correctly.
Systemic				
Participation process	Extensive but very few with a systems perspective. Very limited on social media and e-participation.	Many best practice descriptions but no comparative studies. Many participative MCDM studies but few comparative analyses.	Role of models and facilitator in model based facilitation. Relative benefits of different participantion approaches. When does modelling activate system 1 or 2 thinking in the participants. Experiments with e-participation with models. Social media in modelling. How do the participants understand models. Cultural effects on the approval and use of modelling. Are the benefits and acceptance of models gender sensitive.	Emphasize systems thinking in problem solving and take a systems intelligence approach. Improve facilitation skills and dialog in model based participation. Raise awareness of the social processes taking place in model use. Discuss the mental models and frames people can have. Use models in a facilitated mode rather than in expert mode.
Negotiations and conflict resolution	Extensive on the general principles.	Very limited on the role of models in environmental negotiations. Decision analysis models are used to communicate preferences and values.	Interactive use of models in negotiations. Ways to help reach agreements with modelling. Role of mental models and emotions in model supported processes.	Focus on the transparency of models and processes used. Try to understand and pay attention the social processes taking place.
Strategic behaviour				
Social interaction	Extensive modelling literature in economics and game theory	There are models of strategic behaviour in evolutionary processes in the nature but very few models of strategic behaviour in environmental management. There is an economics journal called Strategic Behaviour and the Environment.	Impact of strategic communication related to modelling and goals. Is modelling affected by politics or power relationships between the stakeholders?	Beware of gaming and hidden agendas in model use and representation of data.
Culture, gender, interest groups, organizational motives	Social sciences	None?	Can there be cultural reasons for the strategic misrepresentation, availability and reliability of data and preferences. Can interest groups or organizations influence model choice to advance their cause.	Appreciate cultural differences. Beware of cultural effects. Pay attention to motivational biases and greenwashing by modeling.
Modelling environments	None?	None?	Can the choice of modelling approaches be used to advance or favour a specific outcome or result? Does strategic omission/inclusion of variables and impacts take place in environmental modelling. What is the impact of the educational background of the modelers (economics, engineering, environmental) and does it bring in implicit strategic behaviour to favour some modelling approaches. Is the choice between soft and hard models affected by strategic motives?	Is there a risk that model related choices are strategic. Use multiple modelers. Peer review of models. Do stakeholders have equal possibilities to influence the modelling approaches taken?

owners are really committed to improve their understanding and willing to test and evaluate alternative modelling processes. In practice time limitations can, however, become an obstacle to such studies. Anyway doing experiments with students is the first step typically taken in other disciplines when studying behavioural issues and this would also get us started.

8. Conclusions

In today's world, models are being used to solve and to help understand complex environmental problems. Modelers with high ethical standards must be open to acknowledge the risks of behavioural effects. Some biases can be unintentional consequences of cognitive limitations others can be strategically motivated omissions or over or under emphazisations of aspects.

Discussing and studying these behavioural risks and possibilities will help to improve trust in modelling. These questions relate to the role of values in socio-environmental modelling. As strongly noted by Voinov et al. (2014) applied science is not value free. Value dependence is a strong driver of behavioural effects.

Behavioural research in environmental modelling can become an important topic in the same way as behavioural studies have established their role in other disciplines. This theme could cover and bring together different kinds of researchers who deal with the analysis and study of behavioural effects having an impact on modelling and the related data elicitation processes. The use of modelling to understand and explain people's behaviour in environmental processes and settings would be included as well as people in the loop models (Fraternali et al., 2012). The research agenda that we suggested for the behavioural OR field also provides environmental modelers a list of possible research themes (Hämäläinen et al., 2013).

The fact that we as modelers are subject to cognitive as well as motivational biases can at first be somewhat difficult to accept. We would like to see ourselves as sincere and bias free truth seekers. However, on the second thought we can still hold on to this image by acknowledging our cognitive challenges and trying to develop as bias free modeling approaches as possible.

I believe, setting up a research agenda in the behavioural issues of modelling will benefit the environmental modelling communities in getting increased approval for their work and better serve the environment and people.

Understanding behavioural aspects from cognitive biases to communication styles is key in creating a fruitful participation process based on systems skills which also recognize the social and motivational factors in the process. How to do this in practice is also an open research theme.

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