Risk Response

an adversarial discourse game and group modelling tool

Max Willis[1 [0000−0001−9718−4966]], Greta Adamo[1,2 [0000−0001−8108−2383]], and Anna Sperotto[3,4 [0000−0002−7443−646X]]

[1] Universitat Politècnica de València, València Spain
{mwillis}@upv.edu.es
[2] Free University of Bozen-Bolzano, Bolzano, Italy
{Greta.Adamo}@unibz.it
[3] Cà Foscari University of Venice, Italy
[4] Basque Center for Climate Change, Leioa, Spain
{anna.sperotto}@bc3research.org

Abstract. Communication of risk, e.g. posed by floods, heatwaves, or infrastructure failure, intends to reduce impacts, limit damage and ultimately save lives, as well as foster people's adaptive and coping capacities to future events. Yet risk is a complex, semantically overloaded and at times ambiguous notion, which affects its understanding and management. In addition, risk communication is influenced by factors such as expert/non-expert knowledge exchange, imbalances of top-down approaches, trust, and empowerment. In response to this, participatory and community-oriented strategies, including game-based interactions, have been implemented to support risk management through stakeholder engagement. Joining this conversation about participation in risk communication, this paper presents *Risk Response*, an adversarial discourse game that facilitates discussion of future environmental, social and technological risks, and appropriate responses to them. The game offers a card-based interaction which mediates (i) conversational play (LEVEL I), in which players speculate on risks and imagine responses, and (ii) group modelling play (LEVEL II), wherein teams engage in semantically enriched conceptual modelling using ontology-based formalisations. This article describes the background, design and play of the game, with a preliminary evaluation of in-game group modelling enacted during a workshop that demonstrates semantic alignment using ontologies in participatory risk communication.

Keywords: Risk · Game and play · Participatory practices · Group modelling · Ontologies.

1 Introduction and motivations

Risks can be of many kinds, e.g. floods, earthquakes, heatwaves, fires, data breaches, identity theft, and pandemics. Hence risk analysis, assessment, and management are constitutive of several fields, e.g. environmental and climate change sciences, finance, engineering, cybersecurity, Artificial Intelligence and public health, and present a long and articulated history [7]. Despite its established literature, understandings of risk and risk management are hindered by overloaded and unclear semantics [1,38], which complicates their communication to ensure effective planning and responses [8, 27, 43, 50]. As the primary goal of risk communication is to mitigate and reduce impacts and losses, understanding and crafting appropriate information dissemination strategies is a priority to reach widely diversified audiences [43, 50]. For instance, to reduce and mitigate the disaster risks of hydrological or seismic hazards, mastering safety drills can prepare civilians to respond, during and after such events, and awareness of evacuation routes and sites of refuge can ensure that at-risk populations are able to exploit these resources. However, risk and response communication can at times be ineffective, owing to mismatches in communication styles, information overload, perceived power imbalances associated with top-down, expert-driven directives, overly technical communication, mistrust of authorities, and uneven sharing of responsibilities [27, 41, 43, 50]. Consequently, the necessity to identify, develop, and evaluate participatory and community-oriented practices for effective risk information delivery and communication becomes an imperative. This requires a shift in communication in which publics are addressed not merely as deficient receivers of information, rather as active participants with agency to shape the interaction [41, 43, 50]. This objective has been widely addressed using game and play techniques (e.g. [28, 41]), and in this paper, we present *Risk Response*, an adversarial discourse game that contributes to risk communication and participation discussions by (*a*) proposing a participant-initiated, risk-agnostic scenario generator to ensure flexibility and ownership of the discourse, (*b*) balancing stakeholder communication and information dissemination through adversarial discourse, and (*c*) facilitating in-game, *ontology-based group modelling* to formalise the semantics of pluralistic risk and response discussions. Risk Response examines environmental, social and technological risks, and accommodates a wide range of stakeholders as participants and gameplay contexts, offering two levels of play in a card-based format. Level I engages participants in *conversational play*, derived from common-sense, collective intelligence and speculation about future risks and responses. Level II leads participants in *group modelling play*, introducing ontology-based conceptual models and the collaborative design of model artefacts to align the semantics of risk and response discourse. This work describes the premise, design and play of the game, with a preliminary evaluation of group models and gameplay from a workshop held at the *18th Research Challenges in Information Science* (RCIS 2024)[5] in Guimarães (PT). The game and modelling activities can be useful for organisations for risk communication, and for development of information systems to identify semantic and thematic congruences in map- and graph-based climate change and risk analyses.

The paper is structured as follows: Section 2 introduces background knowledge on risk and its communication. Section 3 details the Risk Response game,

[5] `https://www.rcis-conf.com/rcis2024/`

Section 4 offers an initial evaluation, followed by related works, discussion and limitations, in Section 6 and 5, conclusions and future works in Section 7.

2 Background knowledge

Risk and related notions. The significance of the notion of risk and its definitions is an established discourse, e.g. [7, 9, 38]. Many fields have dealt with risk, its assessment, and management [7], leading to the development of various types of risks and associated concepts, each tailored differently depending on the context of application. It is beyond the scope of this article to dissect the concept of risk and its understanding, hence we begin with a general, domain-independent definition of risk as *"a situation or event where something of human value (including humans themselves) has been put at stake and where the outcome is uncertain"* [37], after Sales et al. [38]. The latter outlines the three core tenets of this definition as (i) the dependencies between risk and the possible effects on an agent's *interest* (i.e. what agent x values, for example their health and well-being), (ii) the connection between risk and *uncertainty*, particularly for its assessment, and (iii) that risk concerns *possibilities* and futures.

The scientific community has not yet agreed on the semantics of many of risk-related terms, a problem highlighted in [39], and there is a need to establish common grounds, especially in multi-stakeholder settings where mutual agreement and shared understandings play a crucial role. Despite the different definitions used, the international community, via institutions such as the United Nations Office for Disaster Risk Reduction (UNDRR)[6] and the Intergovernmental Panel on Climate Change (IPCC),[7] aim to agree on a set of "key risk components," as follows. (i) **Hazard** is the occurrence of an event or process that might have negative consequences; hazards can be of different types, such as meteorological, hydrological, biological, technological, and societal, and can be either natural or human-made [17]. A typical hazard could be the occurrence of extreme rainfall in a short time-period, such as that which facilitated the disruptive flood that occurred in Valencia in October 2024. (ii) **Exposure** describes the presence of elements (e.g. people, infrastructure, ecosystems) that might be affected by a hazard. In the Valencia example, exposure includes the people, households and businesses located in the municipalities affected by the flood, such as Paiporta. (iii) **Vulnerability** relates to the susceptibility of the exposed elements to suffer damage or loss from a hazard, influenced by factors such as their capacity to respond or to adapt. In the Valencia flood, vulnerabilities included factors such proximity to water bodies, the age and mobility of affected populations, and a mismatch between weather forecasting and activation of warning systems. Accordingly, risks are future, possible, multi-scale dynamics resulting from the complex interaction among the key risk components.

The occurrence of an adverse event can result in a system experiencing actual consequences or negative outcomes, which can induce critical socio-environmental

[6] `https://www.undrr.org/drr-glossary/terminology`

[7] `https://apps.ipcc.ch/glossary/`

disruptions, such as loss of life, infrastructure damage, or failure of system function. Such consequences are often referred to more generally as **impacts** (IPCC) [4] or **disasters** (UNDRR).[8] Once risk and its consequences have been assessed, risk management comes into play. This can be defined as coordinated efforts to monitor, minimize and control the probability or adverse impact of events through the implementation of appropriate response measures [24]. Response measures can be loosely differentiated into **risk reduction measures**, which aim on reducing the likelihood or severity of risks, and **adaptation measures**, which focus on adjusting systems, infrastructure, and practices to cope with the impacts. For example, while appropriate river bank management can mitigate the risk of flood events by reducing the likelihood that extreme rainfall becomes a hazard, early warning systems and effective risk communication plans can help adapt to the impacts of potential floods by preventing or alleviating the associated losses, i.e. reducing exposure and vulnerability.

Risk communication and participatory practices. Risk communication is an evolving and dynamic field rooted in risk management [11,42], with branches such as health, environmental and emergency management [42]. To be effective, it must overcome some of the core challenges of science communication, which suffers from a range of issues related to the dominance, and rejection of expert-led narratives in public discourse (see [15] for an overview). Three paradigms of risk communication have been identified, which can be seen as engagement scales [11, 27, 43]. These paradigms are not exclusive XOR, neither are they an historical evolution, rather are overlapping styles of communication based on particular (often site- or community-specific) exigencies, requirements, and contexts [27]. In the *deficit* model, experts inform citizens of the risk, or potential danger of x, e.g. the public needs to be informed about the nature of COVID-19 in order that they prevent transmission, and health experts as the gatekeepers of (technical) knowledge must translate and transmit that knowledge to the public [15,27,43]. This mode of engagement can be experienced by non-scientific stakeholders as overly technocratic and can lead to disconnect, even willful disbelief due to mistrust of scientific establishments. In the *dialogue* model, attempts are made to improve information delivery by engaging stakeholders in discussion, for example with interviews, surveys and focus groups, through which citizens are "given opportunity" to share their perspectives [43]. This mode of communication, ostensibly inviting stakeholders to engage in risk discourse, can be perceived as simply another way for experts to exert the dominance of their information, and persuade stakeholders to correct courses of thought and action [27].

A third, increasingly adopted, paradigm of risk communication is the *participation* model, which emphasises community-engagement and focusses more on developing relationships between the experts, policy-makers, civil society and publics to ensure mutual-learning and understanding, and empowerment of people experiencing risk on the ground [43]. Such community-oriented and stakeholder-focussed communication initiatives adopt methods from social sci-

[8] `https://www.undrr.org/terminology/disaster`

ence, *à la* Action Research and co-production, to gather together the plurality of perspectives, lived experiences, and skills for participatory sense-making on the subject [48]. Local communities can be engaged inside and outside traditional spaces, such as in cafes, bars and community centers, using more humanistic means of communication including poetry, story-telling, drawing, music, theater and games [43]. As risk discourses are decidedly futures-oriented, the participatory mode of communication incorporates many aspects of *futuring* [20], such as speculative enactment, counterfactual histories, and design fiction. Serious games and gamification have been extensively applied in this context to facilitate mutual learning about risk, and disaster risk management in particular [41]. Role-playing and simulation offer proven potentials to mediate multi-stakeholder, multi-perspective engagement [28], and as games themselves are less formal communication styles, they allow for a more horizontal worldview sharing between policy-makers, volunteers, scientists and publics [41]. However games applied to risk contexts also present some limitations [41], hindering their applicability and scientific relevance. For example (*a*) many game designs are overly specific, targeting a singular hazard or a particular community, and as such are less applicable to other situations. This specificity can lead to (*b*) shortfalls in addressing broader ecological, social and technological understandings of risk and risk management. In addition, (*c*) many risk-orientated games lack proper testing and evaluation methodologies [41].

In redress of the aforementioned limitations of games for risk communication, we present the adversarial discourse game called Risk Response,[9] and in the following discuss its origins, interaction design, material components, rules and gameplay, with a preliminary empirical evaluation.

3 Risk Response game

Risk Response is an adversarial discourse game that examines future environmental, social and technological risks, and human mitigation and adaptation responses to them. Gameplay in Risk Response is designed not to inform or educate on risk, rather to **enact the collectivism** which underpins the intergovernmental bodies' science-based risk investigation, to **spark intuition** on the interrelation of adaptation and mitigation paradigms, and ultimately to **prompt semantic alignment** in risk communication through ontology-based group modelling. The game aligns with initiatives to foster *Futures Literacy* and anticipation, acknowledged by UNESCO as fundamental skills for individuals, communities and societies to navigate the challenges of the emerging future [46]. Risk Response was not developed following an established game design framework, yet it draws practical inspiration from renowned game concepts, such as Nealen's minimalist game design analysis [33], maintaining simplistic game rules and mechanics that facilitate a broad range of play possibilities. Cook's loops and arcs concept is also applied [16], to scaffold learning and player engagement,

[9] `https://doi.org/10.5281/zenodo.13303514`

as are Bogost's theoretical groundings on procedural rhetorics [13] reinforce perspective shifts through implicit communication within the game artefact, its rules, and gameplay contexts. Risk Response also draws from *speculative design* [5] to drive critical interactions that embody and enact futuring concepts as in [6, 18, 20, 46] through game and play.

The game's design follow dual objectives, the first focused on the *game artefact*, e.g. the game must engage a wide variety of participants and perspectives, it must be straightforward to learn, and fun to play. The second track of constraints addresses the *game objectives* of (i) making complex notions of future environmental, social and technological risks understandable and accessible, (ii) driving discourse, using explicit futures concepts, on the interrelatedness of various risk mitigation and adaptation paradigms and (iii) aligning participant perspectives with shared semantics via ontology-based group modelling, which also provides for (iv) an evaluation mechanism to analyze engagement and sense-making potentials of the game (see e.g. [48]).

3.1 Game cards, rules, and modes of play

The Risk Response game design was inspired from the second and third authors' collaborative work on an *ontological unpacking of climate change risk* [1], which aimed at clarifying the semantics of climate change risk and related definitions, e.g. impact and uncertainty, proposed by the IPCC in their *6th Assessment Report* [29]. To aid in sense-making of the complex ontological analysis, the game was prototyped, and following repeated playtests, expanded with the futures perspectives of the IPCC's *5th Assessment Report* [26], the UNDRR 2021 *Hazard Information Profiles* (HIPs) [45], and various futures literature (e.g. [46,47]). The game cards are divided into three groups, the first includes 13 *Risk or Impact* cards, each labeled at the top with a general rubric, or framing of a potential risk, such as *Fire*, *Technology*, or *Social* risks. On each risk card is a set of examples; *Fire* risk or impact examples include *Atmospheric Temperature*, *Stronger UV Rays*, *Forest Fires*, *Urban Heat*, and suggestions for *Social* risks or impact include *Economic Instability*, *Resource Conflict*, *Intangible Cultural Heritage*, and *Migration*, among others. Each card's list of examples ends with *etc.*

The second set of 12 cards are response cards, labeled *Mitigate or Adapt*, categorised into rubrics such as *Citizens*, *Governance* and *Technology*, with suggestions. For example, *Citizens* responses include *Reduce-Reuse-Recycle*, *Green Mobility*, *Activism* and *Volunteering*, and *Population Control*, while the *Technology* card suggests *ICT for development*, *Earth Observation*, *Geosciences & GIS*, and *AI Solutions*, among others. Each list again ends with *etc.* The third set of 15 cards are the game's *Discourse cards*, with progress discussion contributions, e.g *Sustainable Action* and *Resilience*, inhibiting directions, such as *Immutable Status Quo* and *Hidden Danger*, and several terminal discourse cards, such as *Futures Judgment*, *Catastrophe*, and *Move to Mars*. Each card contains instructions on how the concept can contribute to the game discussion, e.g. *Stroke of Luck* could be used against overly realistic play, and *Catastrophe* can be played to counter overly optimistic discussion. Table 1 lists the complete set of cards.

Table 1: *Risk Response* cards.

Risk or Impact	*Mitigate or Adapt*	*Discourse card*
Air	*Citizens*	*Resilience*
Fire	*Governance*	*Equilibrium*
Water	*Organisations*	*Blue-Green Future*
Earth	*Education*	*Sustainable Action*
Ocean	*Health*	*Anticipation*
Sound and Light	*Society*	*Knowledge Commons*
Vegetation	*Economy*	*Immutable Status Quo*
Animal	*Food Systems*	*Hidden Danger*
Food	*Services*	*Uncertainty*
Social	*Environment*	*Response Outcome Risk*
Technology	*Resource*	*Future Judgment*
Built Environment	*Technology*	*Catastrophe*
Extraterrestrial		*Stroke of Luck*
		Time Machine
		Move to Mars

Additional blank risk cards are also available, for gameplay in participatory project development settings where particular themes or site-specific risks need to be analyzed.

Finally, the *Futures Cone* completes the game's material aspect (Figure 1 Left). This speculative design tool describes potential future trajectories moving from the present, on the left, to the future on the right. Concentric circles, (cones) demarcate the temporal areas of Possible, Preferable, Plausible and Probable futures. At the outermost fringes of the Futures Cone are located Wildcards, that are low-probability events, and Preposterous futures, which although they are highly unlikely to happen, remain within human imagination. The Futures Cone has undergone many developments and reinterpretations since its introduction to defense studies in the 1980's [21]; the version used in Risk Response has been adapted by the first author from [47].

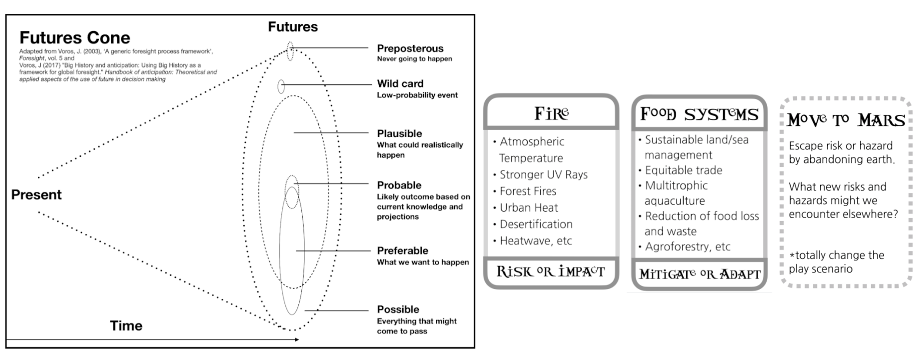

Fig. 1: Futures Cone (Left); Sample Risk Response cards (Right).

Game rules. The game's basic format consists of: players forming two teams, *Team Risk* and *Team Humanity.* Team Risk proposes a risk and outlines its impact, after which Team Humanity proposes a response, based on cards randomly drawn from the decks (see a sample of Risk Response cards in Figure 1 Right). Team Risk is implored to play impartially, imagining and portraying their proposed risk as data-driven and inevitable. Team Humanity is encouraged to an impassioned play, focusing on visionary, innovative potentials that humanity has can use to manage risk. The two teams debate the plausibility of Team Humanity's response, and spectators are invited to join in the discussion, referring to the Futures Cone. A subsequent vote on the possible future, and whether the response outcome proposed by Team Humanity is Plausible, Probable or Preposterous, decides the winner of the round, if that team is convincing in their argument, or supported by terminal discourse cards. Teams are then reconfigured, typically by revolving one player at a time to the right, the cards are shuffled and redistributed for the following rounds, which continue until each participant has had the opportunity to play on both Risk and Humanity teams.

The gameplay rules are: Team Risk randomly draws ONE (1) *Risk or Impact* card, and must devise a risk proposal within that rubric, although not necessarily choosing from the suggestions (hence the *etc* at the end of each list). Team Humanity randomly draws TWO (2) *Mitigate or Adapt* cards, and their response to the proposed risk must be framed in relation between those two rubrics. Each player, and any spectator who wishes to participate, randomly draws ONE (1) *Discourse card*. These cards can be played by any player, or spectator, at any time to influence the discussion. Several of the discourse wildcards offer final decisions which allow to break an impasse, or when the futures vote is tied.

Conversational vs group modelling play (LEVELS I AND II). In conversational play (LEVEL I), the game is played based on common-sense, drawing from players's collective intelligence to imagine and describe risks and responses. This level represents the first loop in which players are introduced to the rules and play possibilities provided by the different cards and mechanics. In these first gameplay encounters, questions and challenges to the minimal rules are sounded out, and the teams decide for example on the style of voting, e.g. a show of hands, unanimous or simple majority. After playing at least one round in conversational mode, which lasts approximately 20 minutes, and depending on the context of play (e.g. if the game is instantiated in a formal workshop, at a conference social event, or an informal game night among friends and colleagues), players can advance to the next level.

The second level of play is ontology-based group modelling (LEVEL II), which follows the same team setting, risk and response proposals, Futures Cone discussion, and plausibility vote, yet with the addition of a printed *reference semantic model/framework*, such as ontology-based conceptual models or Knowledge Graphs. Example of those could be the *social-ecologial systems (SESs) integrated conceptual model* [2, 3] and the *Common Ontology of Value and Risk* (COVER) [38]. For this mode, one new game rule is implemented: when Team

Risk proposes their risk they must create a conceptual model following the reference model, describing some aspects of their risk, e.g. what is the hazard and who or what is potentially affected (exposure). Likewise, Team Humanity must model their response, using the same reference model. Teams can then use their models to elaborate, articulate and argue for their risk and responses in the discourse. At the conclusion of each round, which typically lasts about an hour, the risk and response models are labeled and collected for later analysis. Figure 2 captures group modelling in action.

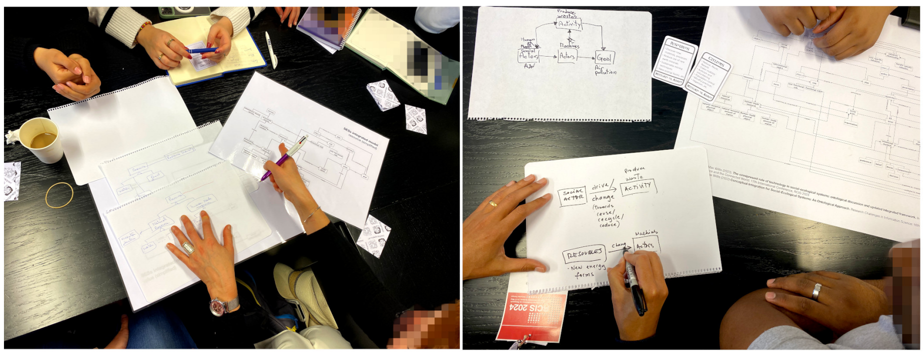

Fig. 2: Risk Response group modelling play (LEVEL II).

4 Preliminary evaluation

This section highlights preliminary evaluation results obtained from the participatory workshop *Exploring ontology-based design interactions for sustainability research*,[10] organised and facilitated by the first two authors at RCIS 2024. The **goal** of this evaluation is to examine the use, by participants, of ontological notions to effect semantic alignment in risk communication.

4.1 Context and participants

The workshop introduced and investigated ontology-based participatory sense-making approaches for social-ecological systems research (see [48]), with activities centered around an ontology-based SESs integrated conceptual model, from [2,3]. These included an icebreaker to discuss relations in the model, graphical scenario analysis using the conceptual model, and Risk Response gameplay. The ontology-based SESs integrated model captures main elements of two social-ecological systems paradigms, the *social-ecological system framework* [30] and the *ecosystem services cascade* [36], via ontological analysis, using for example the

[10] `https://humanfactorsinsemantics.net/RCIS2024.html`

Unified Foundational Ontology [25], for their ontological disambiguation and integration. The model includes concepts such as *ecosystem service*, *structure*, and *function*, *actor*, *social actor*, *organisation*, *governance*, as well as *resource system*, *natural resource human-made resource*, among others. It has been refashioned in the *Web Ontology Language* (OWL2) and can be found in GitHub.

Forty-five (45) workshop participants engaged in Risk Response gameplay, including a large, multicultural contingent of masters students from information systems studies. Four (4) groups of 8 to 12 participants formed teams of 5 or 6 players each for Team Risk and Team Humanity. After playing a round in LEVEL I conversational play, the four groups switched roles for a round of (LEVEL II) group modelling play, each completing the **tasks** of risk and response modelling following the SESs integrated conceptual model as a semantic reference.

4.2 Results

Our frames of analysis elucidate *quality dimensions* in conceptual models, in line with longstanding discussions in Software Engineering and Information Systems literature (e.g. [12, 22, 34]). We focus on *modelling styles and techniques*, correct use of *model concepts and relations*, *cross-model semantic alignment*, and ethnographic observations of *models in communication*. Primary data are the group models created during gameplay, photographic evidences and observations of the first two authors as workshop facilitators. The group models can be viewed in the shared folder. In the following report, reference model components are named in lower-case *italic*, and components introduced by participants are written, first letter capitalised, in `Courier`.

Modelling styles and techniques. Several distinct modelling practices can be observed in the group models. In Groups 1 and 2, Team Risk first created a model of their proposed risk and Team Humanity created a corresponding model of the proposed response ("dual modelling"). Team Risk in Groups 3 and 4 first created a model of the proposed risk, and Team Humanity *extended* that model with their response ("singular modelling"). The use of relations arrows also differed between groups: for example in Group 4's model, we find mostly unlabelled relations following the reference model standard of defining subsumption using closed-head arrows, as in UML, while in Group 1's risk model, variant arrows are used, yet these are labelled with the proper relations from the reference model. The other groups and teams employed a variety of open arrows and connecting lines. In all of the group models, response modelling generally follows the style for concepts and relations set by the risk teams, and in the groups practicing singular modelling, players differentiated between risk and response using different colors of ink. As participants were not given detailled modelling instructions, the emergence of similar practices among different groups is noteworthy.

Correct concepts and relations. We considered as evaluation parameter the uptake and correct use of concepts from the SESs reference framework, first examining the group models for *explicit semantics*, i.e. terminology adopted directly

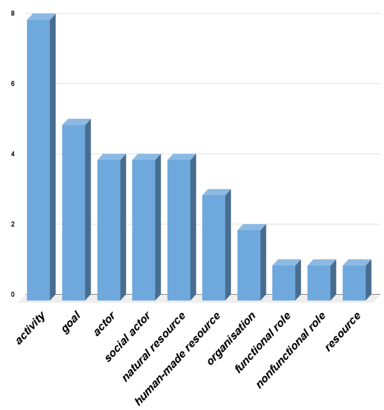

Fig. 3: Correct categorisation.

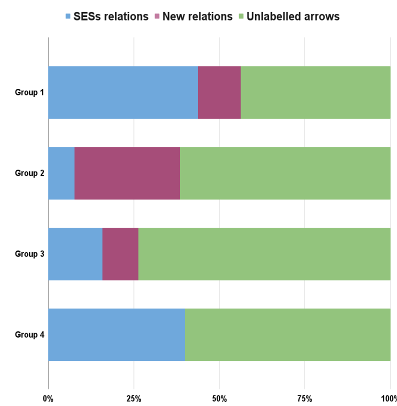

Fig. 4: Use of relations.

from the reference model, either as labels for named concepts, or as primary class or sub-class entities depicted in their models. Secondly, the group model concepts were examined for correct *implicit semantics*, identifiable by their named relations and position in the model. Considering the risk model of Group 1 (dual modelling), we find only one reference ontology concept, in the depiction of `Humanity` *has* the *goal* of `Survival`. This is counted as one marker of explicit correctness. In that model, thirteen (13) additional concepts describe impacts of Vegetation risks, such as `Deforestation` and related `Habitat Loss`, none of which are found in the reference model. However, the proper use of five (5) reference model relations, several applied multiple times, reveal eight (8) more correct uses of implicit semantics. For example, `Pesticide Use` is identifiable as an *activity*, because it is *performed_ by* `Humanity`, itself properly placed as a *social actor*, due to the *creates* and *recognized_ by* relations drawn to *human-made resources* and *natural resources*. Figure 3 depicts the most common, correctly used reference model concepts, of which *activity* and *goal* are predominant, followed by *actor*, *social actor*, *natural-resource* and *human-made resource*.

Cross-model semantic alignment. In group modelling, cross-model analysis makes possible to identify emergent shared understandings, wherein model concepts and relations are re-fashioned or corrected in subsequent collaborative modelling operations. For instance, the risk model of Group 2 (dual modelling approach) describes Air pollution using four (4) concepts from the reference model: `Humans` as *social actors*, and `Machines` as *actors* are connected to *activities* which `Produce Waste` with the *goal* of `Air Pollution`. This model incorporated no named relations. In reply, Group 2 Team Humainty reformulated the same four reference concepts, to show `Human` and `Electric Machines` as *social actors* related to *activities* with the *goal* of `Clean Air`. Players modelled *resources* and `government` (echoing *governance*) in a response that demonstrates multiple correct implicit semantics, for example of `Policy Making`, recalling the reference model's *policy*. Though not all model concepts and relations are correct, the response model offers some semantic clarification of the risk model, in particular concerning governance, policy and regulation, that directly reflects participants' engagement with the ontology of the reference model.

Group 3 used singular modelling, and iteratively built on each other's ideas concerning Vegetation risk. Team Risk modelled the risk posed by Genetically Modified Organisms (GMO's) relating to `Government` and *policies*, with a new relation `Enforced_by`, and several *organisations*, using 10 unlabelled relations arrows to draw connections. Group 3 Team Humanity added two `Activism` elements, and described future impacts of *policies*, *organisations* and `Consumers`. Their relations clarify the original risk model: `Activism` is an *activity* that is *performed_ by* the *social actors* of `Consumers` and `Food Regulation Organisation` and furthermore that `Disease Prevention and Control` is a *goal associated to* the *activity* of `Governmnent`, which though is misspelled, is in complete semantic alignment with *governance* from the reference model. In these cases the correct use of relations facilitates semantic alignment, and serves to correctly categorise concepts from the first model, according to the reference model. Figure 4 shows the different group models' correct use of relations, newly introduced relations, and unnamed modelling arrows. Groups 1, 3 & 4 all used more relations from the reference model, with only Group 2 requiring more imagined relations to communicate their idea. Group 4's model is noteworthy as its only relations come from the reference model, and while there are many variant arrows and connecting lines, it was this group that used explicit *is_ a* closed arrowhead relations connectors, strictly aligning with the reference model's composition.

Models in communicative action. One of the goals of conceptual models is to foster communication and understanding [32], topics widely discussed in literature. We isolate from participant observations, a particular kind of *embodied* communication involving the models themselves. During the preparation of the group models, anf gameplay discussions, players frequently gestured and traced relations across the group and reference models. This physical engagement with cognitive and material artefacts to effect communication, also known as embodied sense-making (see [48]), is less present in LEVEL 1, conversational play, and emerges with the introduction and creation of model artefacts in LEVEL 2 group modelling play. Such communication is further evident in the distinct practices adopted by players, of using the models as communication tools. During discussion and voting, players most often placed their models on the table, together with the Futures Cone, pointing out concepts and relations as they debated possible and plausible futures. In one group, a player held their team's model up for the other players to see, explaining each model concept and relation; in another group, a player held their team's model facing themselves, explaining their ideas using the model as a guide, rather than explaining the model. The emergence among four groups of players, of multiple, distinct embodied communication styles involving the model artefacts suggests that the game-based group modelling activity is broadly inclusive of participants' differing expressive exigencies discursive styles, and demonstrates the communicative affordances of conceptual models as discursive artefacts.

5 Discussion and limitations

In discussion we offer some critical reflections on Risk Response, its relation to risk communication and some limitations of the group modelling activity and evaluation. The game's execution activates collective intelligence that is central to the intergovernmental bodies which have produced risk-related documents on which the game is based. Participants generate the risks for discussion, brainstorm mitigation and adaptation responses, then speculate and vote on the possible or plausible futures, thereby up-ending and reinterpreting the conventional science communication and policy-decision paradigms. This aspect figures into the previously discussed transformation from information deficit, to dialogue and participation in risk communication.

In LEVEL 2 group modelling play, the game's minimal rules and instructions allow players to decide if one, or multiple players will draw the model, and how to interpret reference ontology components. While this offers players flexibility to interpret modelling as a communicative act, it poses some limitations to the execution and evaluation of models produced in-game. These models do not capture the discourse of gameplay, argumentation of players, evolution of ideas, nor the engagement and intrigue that can be triggered by the Futures Cone and plausibility vote. All of these have been observed by the authors as workshop facilitators, especially when teams try to convince eachother of their imagined future. Neither do the models record the use of, and envelopment of spectators provided by the discourse cards. Photographs taken during the workshop offer additional insights into group modelling and discursive processes during gameplay, however the authors deliberately refrain from video or audio surveillance. This omission, while retaining a familiar, relaxed environment for participants, requires that some analyses remain interpretation, based on tacit knowledge derived from the authors' many previous ethnographic studies via participatory practices and workshop facilitation, enacting conceptual- and cognitive modelling towards interaction design research (e.g. [49]).The researchers' implicit bias can endanger evaluation validity, and as players are given the directive of modelling a response to a proposed risk using a reference model, it is almost assured that their models will reflect the ideas of both the reference model and those of other participants. However, the completed models (and model pairs) of all four groups depict active engagement between teams, and elaboration of each other's ideas using the structures of the reference models as they further define, semantically align, and communicate concepts and their relations.

6 Related works

The tool and approach proposed in this paper combines gameplay, group modelling, ontology-based semantic alignment, and in-game evaluation strategies, characteristics that cannot be found in other related games and research literature. Yet Risk Response does not emerge from a vacuum, and numerous educational and/or serious games addressing risk exist (see [41] for a detailled review). These are largely simulation boardgames concerned with Disaster Risk Management, that leverage role-play for multi-party discourse and information sharing. Typical examples of the genre are *Hazagora* [31], a serious game for students and administrators to increase their awareness of geohazards and disaster risk reduction, and *ANYCaRE* [44], a role-play game focused on crisis management, forecasting, and early warning of flash floods, or strong winds. A more academic entrant is the *RAMSETE* series [19] of information elicitation games on disaster risk and climate change adaptation, set within European policy space. Evaluations of these games, when are performed, rely on post-experience questionnaires and notes taken by facilitators. In contrast Risk Response allows evaluation of models produced *during* gameplay. In addition, while most risk games revolve around group discussions and collaborative action [41], none that we have found explicitly aim to align, or analyze the semantics of such discussions.

The intermittent academic investigation of games for participatory modelling stems can be traced to Bousquet et al. [14] seminal work, wherein stakeholders role-play and roughly craft models of resource use and conflicts, regarding for example irrigation systems and agroforestry, which are then formalized as computer simulations. Perez et. al. subsequently offered *ComMod* [35] in which role-playing, model creation, and simulations are blended in a knowledge elicitation practice. More recently Bakhanova et.al [10] acknowledge many potential benefits of games for participatory modelling, however the in-game modelling is far from established practice. Risk Response, by combining game, discourse and group modelling, and by integrating ontologies for semantic alignment in player discussions, opens a new direction in this field.

7 Conclusions and future works

This article contributes to discussions on participatory risk communication by introducing the adversarial discourse game Risk Response, a stakeholder engagement and group modelling tool for examining future risks and associated responses. The game and play are presented, with a preliminary evaluation that elaborates the affordances of game-based group modelling for semantic alignment. An important next step will be to enact more thorough evaluations, in real-world risk analysis settings, playing with domain experts and local stakeholders. Dedicated cards formulated around site-specific risks and localized scientific research can be designed to reflect participants' lived experiences and further operationalize ownership of risk discourse.

The development, playtesting, and evaluation of this game and group modelling outcomes, revealed some potentially useful game revisions, such as extending the socio-political and technological risk suggestions in the cards with themes that repeatedly emerge in gameplay sessions, e.g. loss of democracy or human rights, misinformation, and risks posed by robots and automation. Additional

Discourse cards will add compound risk [40] and multi-hazard [23] concepts to the game, guiding players to imagine aggregate, and cascading risks. In addition, the communicative potentials of group modelling in the game will be sharpened to include map and graph analysis, collating players' identified interrelations between risks, impacts and responses and plotting them in real time.

Acknowledgments. Authors acknowledge the financial support the project D2G2 (DFG grant n. 500249124). We would also like to thank the reviewers for their insightful feedback, our RCIS 2024 workshop attendees for their participation, and the conference organisers for graciously enabling this ongoing research.

References

1. Adamo, G., Sperotto, A., Fumagalli, M., Mosca, A., Sales, T.P., Guizzardi, G.: Unpacking the semantics of risk in climate change discourses (2024)
2. Adamo, G., Willis, M.: Conceptual integration for social-ecological systems - an ontological approach. In: Research Challenges in Information Science - 16th International Conference, RCIS 2022, Barcelona, Spain, May 17-20, 2022, Proceedings. Lect. Notes Bus. Inf. Process., vol. 446, pp. 321–337. Springer (2022)
3. Adamo, G., Willis, M.: The omnipresent role of technology in social-ecological systems - ontological discussion and updated integrated framework. In: Research Challenges in Information Science: Information Science and the Connected World - 17th International Conference, RCIS 2023, Corfu, Greece, May 23-26, 2023, Proceedings. Lect. Notes Bus. Inf. Process., vol. 476, pp. 87–102. Springer (2023)
4. Andy, R., et al.: The concept of risk in the ipcc sixth assessment report: a summary of cross- working group discussions. guidance for ipcc authors. Tech. rep. (2020)
5. Auger, J.: Speculative design: crafting the speculation. Digital Creativity **24**(1), 11–35 (2013)
6. Auger, J., Hanna, J., Encinas, E.: Reconstrained design: Confronting oblique design constraints. Design+ Power. Nordes, Oslo (2017)
7. Aven, T.: Risk assessment and risk management: Review of recent advances on their foundation. European Journal of Operational Research **253**(1), 1–13 (2016)
8. Aven, T.: Perspectives on the nexus between good risk communication and high scientific risk analysis quality. Reliability Engineering & System Safety **178**, 290–296 (2018)
9. Aven, T.: Is the definition of risk still contested? (2023)
10. Bakhanova, E., Garcia, J.A., Raffe, W.L., Voinov, A.: Targeting social learning and engagement: what serious games and gamification can offer to participatory modeling. Environmental Modelling & Software **134**, 104846 (2020)
11. Balog-Way, D., McComas, K., Besley, J.: The evolving field of risk communication. Risk Analysis **40**(S1), 2240–2262 (2020)
12. Becker, J., Niehaves, B., Pfeiffer, D.: Ontological evaluation of conceptual models. Scand. J. Inf. Syst. **20**(2), 4 (2008)
13. Bogost, I.: Persuasive Games: The Expressive Power of Videogames. The MIT Press (06 2007)
14. Bousquet, F., Barreteau, O., d'Aquino, P., Etienne, M., Boissau, S., Aubert, S.: Multi-agent systems and role games: collective learning processes for ecosystem management. In: Complexity and ecosystem management, pp. 248–285. Edward Elgar Publishing (2002)

15. Bucchi, M.: Of deficits, deviations and dialogues: Theories of public communication of science. In: Handbook of public communication of science and technology, pp. 71–90. Routledge (2008)
16. Cook, D.: Loops and arcs **2016**(Nov 5) (2012), `http://www.lostgarden.com/2012/04/loops-and-arcs.html`
17. for Disaster Risk Reduction (UNDRR), U.N.O.: Hazard definition and classification review: Technical report. Tech. rep. (2020)
18. Elsden, C., Chatting, D., Durrant, A.C., Garbett, A., Nissen, B., Vines, J., Kirk, D.S.: On speculative enactments. Proc. of CHI 2017 pp. 5386–5399 (2017)
19. Fleming, K., Abad, J., Booth, L., Schueller, L., Baills, A., Scolobig, A., Petrovic, B., Zuccaro, G., Leone, M.F.: The use of serious games in engaging stakeholders for disaster risk reduction, management and climate change adaption information elicitation. International Journal of Disaster Risk Reduction **49**, 101669 (2020)
20. Fry, T.: Design futuring. University of New South Wales Press, Sydney pp. 71–77 (2009)
21. Gall, T., Vallet, F., Yannou, B.: How to visualise futures studies concepts: Revision of the futures cone. Futures **143**, 103024 (2022)
22. Gemino, A., Wand, Y.: A framework for empirical evaluation of conceptual modeling techniques. Requir. Eng. **9**(4), 248–260 (2004)
23. Gill, J.C., Malamud, B.D.: Hazard interactions and interaction networks (cascades) within multi-hazard methodologies. Earth System Dynamics **7**(3), 659–679 (2016)
24. Glette-Iversen, I., Flage, R., Aven, T.: Extending and improving current frameworks for risk management and decision-making: A new approach for incorporating dynamic aspects of risk and uncertainty. Safety science **168**, 106317 (2023)
25. Guizzardi, G., Botti Benevides, A., Fonseca, C.M., Porello, D., Almeida, J.P.A., Prince Sales, T.: Ufo: Unified foundational ontology. Appl. Ontol. **17**, 1–44 (2021)
26. IPCC: Ipcc fifth assessment report—synthesis report. Tech. rep. (2014)
27. Irwin, A.: Risk, science and public communication: Third-order thinking about scientific culture. In: Routledge handbook of public communication of science and technology, pp. 147–162. Routledge (2021)
28. Janssen, M.A., Falk, T., Meinzen-Dick, R., Vollan, B.: Using games for social learning to promote self-governance. Current Opinion in Environmental Sustainability **62**, 101289 (2023)
29. Lee, H., Calvin, K., Dasgupta, D., Krinmer, G., Mukherji, A., Thorne, P., Trisos, C., Romero, J., Aldunce, P., Barret, K., et al.: Synthesis report of the ipcc sixth assessment report (ar6), longer report. ipcc. (2023)
30. McGinnis, M.D., Ostrom, E.: Social-ecological system framework: initial changes and continuing challenges. Ecology and society **19**(2) (2014)
31. Mossoux, S., Delcamp, A., Poppe, S., Michellier, C., Canters, F., Kervyn, M.: Hazagora: will you survive the next disaster?–a serious game to raise awareness about geohazards and disaster risk reduction. Natural Hazards and Earth System Sciences **16**(1), 135–147 (2016)
32. Mylopoulos, J.: Conceptual modelling and telos. Conceptual modelling, databases, and CASE: An integrated view of information system development pp. 49–68 (1992)
33. Nealen, A., Saltsman, A., Boxerman, E.: Towards minimalist game design. In: Proceedings of the 6th international conference on foundations of digital games. pp. 38–45 (2011)
34. Nelson, H.J., Poels, G., Genero, M., Piattini, M.: A conceptual modeling quality framework. Softw. Qual. J. **20**(1), 201–228 (2012)

35. Perez, P., Aubert, S., Daré, W., Ducrot, R., Jones, N., Queste, J., Trébuil, G., Van Paassen, A.: Assessment and monitoring of the effects of the commod approach. Companion modelling: a participatory approach to support sustainable development pp. 155–187 (2014)
36. Potschin, M., Haines-Young, R., et al.: Defining and measuring ecosystem services. Routledge handbook of ecosystem services pp. 25–44 (2016)
37. Rosa, E.A.: Metatheoretical foundations for post-normal risk. Journal of risk research **1**(1), 15–44 (1998)
38. Sales, T.P., Baião, F., Guizzardi, G., Almeida, J.P.A., Guarino, N., Mylopoulos, J.: The common ontology of value and risk. In: Conceptual Modeling - 37th International Conference, ER 2018, Xi'an, China, October 22-25, 2018, Proceedings. Lecture Notes in Computer Science, vol. 11157, pp. 121–135. Springer (2018)
39. Shi, P., Ye, T., Wang, Y., Zhou, T., Xu, W., Du, J., Wang, J., Li, N., Huang, C., Liu, L., et al.: Disaster risk science: A geographical perspective and a research framework. International Journal of Disaster Risk Science **11**, 426–440 (2020)
40. Simpson, N.P., Mach, K.J., Constable, A., Hess, J., Hogarth, R., Howden, M., Lawrence, J., Lempert, R.J., Muccione, V., Mackey, B., et al.: A framework for complex climate change risk assessment. One Earth **4**(4), 489–501 (2021)
41. Solinska-Nowak, A., Magnuszewski, P., Curl, M., French, A., Keating, A., Mochizuki, J., Liu, W., Mechler, R., Kulakowska, M., Jarzabek, L.: An overview of serious games for disaster risk management–prospects and limitations for informing actions to arrest increasing risk. International journal of disaster risk reduction **31**, 1013–1029 (2018)
42. Steelman, T.A., McCaffrey, S.: Best practices in risk and crisis communication: Implications for natural hazards management. Natural hazards **65**, 683–705 (2013)
43. Stewart, I.: Advancing disaster risk communications. Earth-Science Reviews p. 104677 (2024)
44. Terti, G., Ruin, I., Kalas, M., Láng, I., Cangròs i Alonso, A., Sabbatini, T., Lorini, V.: Anycare: a role-playing game to investigate crisis decision-making and communication challenges in weather-related hazards. Natural Hazards and Earth System Sciences **19**(3), 507–533 (2019)
45. UNDRR: Hazard information profiles: Supplement to undrr-isc hazard definition & classification review. Tech. rep., United Nations Office for DisasterRisk Reduction (UNDRR) (2021)
46. UNESCO: Transforming the future: Anticipation in the 21st century. Taylor & Francis (2018)
47. Voros, J.: Big history and anticipation: Using big history as a framework for global foresight. Handbook of anticipation: Theoretical and applied aspects of the use of future in decision making pp. 1–40 (2017)
48. Willis, M., Adamo, G.: Ontology-based interaction design for social-ecological systems research. In: International Conference on Research Challenges in Information Science. pp. 74–82. Springer (2024)
49. Willis, M., De Angeli, A., Zancanaro, M.: Experience probes: Immersion and reflection between reality and virtuality. In: Human-Computer Interaction–INTERACT 2017: 16th IFIP TC 13 International Conference. pp. 253–262. Springer (2017)
50. Yamori, K.: Disaster Risk Communication: A Challenge from a Social Psychological Perspective. Springer Publishing Company, Incorporated, 1st edn. (2020)