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Serious Gaming for Climate Tipping Points

The effects of a role-play simulation game designed for climate negotiators on perceptions of risks and efficacy associated with climate tipping points

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Table of contents

1. Introduction 3
2. Theoretical framework 6
   2.1 Climate tipping points 6
   2.2 Cognition and decision-making in response to climate tipping points 8
   2.3 Theory on perceived risk and efficacy 12
   2.4 The use of serious gaming to change perceptions of climate change 25
3. Hypotheses 31
   3.1 Hypotheses on perceived risk and efficacy 31
   3.2 Hypotheses on the effects of the game on perceived risk and efficacy 34
4. Methods 36
   4.1 Materials and procedure 36
   4.2 Operationalization of variables 43
   4.3 Data analysis 45
5. Results 48
   5.1 Perceived risk and efficacy 49
   5.2 Effects of the role-playing simulation game 64
6. Discussion 66
   6.1 Discussion of results 66
   6.2 Limitations 70
   6.3 Recommendations 73
7. Conclusion 81

References 82
Appendix I The Gaming Climate Futures project 92
Appendix II Game development process 92
Appendix III Personal involvement in the project 93
Appendix IV Survey Instruments 98
Appendix V Quantitative results 100
Appendix VI Qualitative analysis and results 106

Abstract

If countries fail to combat global warming, it is likely that dangerous tipping points of the climate system will be triggered this century, with catastrophic and irreversible impacts on human wellbeing. Although climate tipping points are closely related to global temperature and thus the 1.5°C and 2°C Paris Agreement targets, the issue remains largely ignored in climate negotiators and are often not incorporated in belief systems of the participants of UNFCCC negotiations. Moreover, much is unknown about the way climate negotiators perceive the risks associated with climate tipping points (i.e. risk perception) and the extent to which they feel capable of influencing the likelihood of avoiding tipping points (i.e. perceived efficacy). Psychological research suggests that risk perception and perceived efficacy are important psychological factors underlying climate change action. Therefore, the current research explores these perceptions and how this can be influenced by means of serious gaming. The research reports on findings of the Gaming Climate Futures project, where a role-playing simulation game has been developed in which climate negotiators explore the relationship between global temperature goals and climate tipping points and imagine climate futures following a collective decision-making process. Survey data that revealed a further understanding of risk and efficacy perceptions and the effects of this game on these perceptions was investigated. Results indicated that the risks associated with climate tipping points were perceived as highly serious, although study participants were not convined about the understanding within the UNFCCC regarding appropriate governance responses to climate tipping points. Thus, a mismatch appears between on the one hand lacking understanding and belief in efficacy of the UNFCCC and on the other hand high perceived risk. The role-playing simulation resulted in increased concern, but no change in perceived efficacy. This research emphasizes the importance in addressing the identified mismatch and the potential of serious gaming in this, particularly when combined with a mix of scenario approaches. Thereby, this research provides valuable insights in the role of cognition in global climate negotiations and serious gaming as science-policy interface in global climate governance.

Key concepts: *serious gaming, climate tipping points, risk perception, perceived efficacy, global climate governance, climate negotiations*

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1. Introduction

Despite the efforts of countries to negotiate international agreements to combat anthropogenic climate change, progress towards global climate change goals has been slow (Widerberg & Pattberg, 2015). In the 2015 Paris Agreement, countries agreed to limit global warming to 'well below' 2°C compared to pre-industrial levels and to make efforts to keep temperature increase below 1.5°C (UNFCCC. Conference of the Parties (COP), 2015). If countries fail to combat global warming, it is likely that dangerous tipping points of the climate system will be triggered during the 21st century (Lenton et al., 2008). Climate tipping points are relatively small changes that lead to nonlinear shifts in the dynamics of the climate system, changing its future qualitative state (Lenton, 2011). Research suggests that triggering climate tipping points will likely have irreversible and catastrophic negative impacts on human wellbeing (Cai, Judd, & Lontzek, 2013; Lontzek, Cai, Judd, & Lenton, 2015). The likelihood of triggering climate tipping points increases with increasing global temperature in a complex and non-linear way (Lenton et al., 2008) and recent scientific research suggests that certain tipping points might have already been passed or might be triggered within the 'Paris range' of 1.5°C or 2°C (Schellnhuber, Rahmstorf, & Winkelmann, 2016). However, climate tipping points remain a largely ignored governance issue in international climate negotiations (Milkoreit, 2013). Therefore, there is an urgent need of a shared understanding of climate tipping points and development of appropriate governance responses within the UNFCCC community.

According to Milkoreit (2013; 2015), the lack of engagement with climate tipping points might have a cognitive explanation, as climate negotiation participants fail to incorporate this relatively recent scientific concept in their belief systems. Thus, there seems to be a 'science-policy disconnect' in global climate governance, which raises questions about the current approach of communicating science (Milkoreit, 2013; 2015). Moreover, different negotiation participants are concerned about different types of threats posed by climate change and these threat perceptions highly influence their sense of urgency of climate change action (Milkoreit, 2017). As suggested in psychological research, the perceived likelihood and seriousness of risks (i.e. risk perception) and the perceived ability to influence climate change (i.e. perceived efficacy) are two important factors underlying individual responses to climate change risks (Grothmann & Patt, 2005; Leiserowitz, 2006; Milfont, 2012; O'Connor, Bord, & Fisher, 1999; Spence, Poortinga, Butler, & Pidgeon, 2011). So far, most research has focused on public risk and efficacy perceptions and apart from research by Milkoreit (2013; 2015; 2017), much remains unknown regarding perceptions of participants of international climate negotiations. Moreover, there is a lack of research on perceptions of climate tipping points specifically, which might be different considering the non-linearity, uncertainty and complexity involved. Because appropriate governance responses to climate tipping points are urgent, it is important to study these perceptions among participants of international climate negotiations and how this might be influenced by alternative approaches of science communication.

Because of the complexity of climate system, learning about climate change requires interactive rather than passive learning (Sterman, 2012). Moreover, risk perceptions and decisions under uncertainty involve complex mental processes such as cognitive heuristics and emotions (Leiserowitz, 2006; Sjöberg, 2000; Slovic, Finucane, Peters, & MacGregor, 2007; Tversky & Kahneman, 1974; 1981). Therefore, it is unlikely that passively learning about climate tipping points will be successful in changing perceptions about risks of climate tipping points and efficacy perceptions of responses to those risks. Serious gaming might be a promising tool in this regard, because of the increasing recognition that its learning potential goes far beyond knowledge acquisition only. In research on effectiveness of serious games, outcomes in terms of motivation, attitudes and behavior have been reported in empirical research (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Wouters, Van Nimwegen, Van Oostendorp, & Van Der Spek, 2013). Changes in perceptions of risk and efficacy in situations that involve risks have been reported by a few studies as well (Chittaro, 2012; Tanes, 2017). Recent findings also suggest that serious games might be effective in changing perceptions of climate change specifically (e.g. Rumore, Schenk, & Susskind, 2016; Van Pelt et al., 2015). However, research on the effectiveness of serious games in changing in risk perceptions and efficacy perceptions associated with climate change is still lacking. Moreover, no research has focused on the role of serious gaming in changing perceptions of climate tipping points specifically.

The current research reports on effects of a role-play simulation game ("The Tipping Point Negotiations") that has been developed in the Gaming Climate Futures project by Purdue University (see Appendix I). This serious game designed for participants of climate negotiations aims at deepening players' understanding of climate tipping points and their relationship with global temperature goals. The game also enables players to imagine the long-term consequences of their decisions, in particular the potential impacts of climate tipping points. As part of this project, the current research aims to understand perceptions of risks and efficacy among climate negotiation participants and other professionals that are actively working on climate change, and how a role-playing simulation game might influence these perceptions. This is in line with the following research question: *What are the perceptions of risks and efficacy regarding climate tipping points among climate negotiation participants and other climate change professionals and how does a role-playing simulation game influence these perceptions?* This research question includes the following sub questions: (1) How can perceptions of risks and efficacy regarding climate tipping points be understood in a broader context of climate change action? (2) What are the political implications of changes in risk perception and efficacy in global climate negotiations? (3) How are the risks associated with climate tipping points and efficacy perceived by climate negotiation participants and other climate change professionals? (4) What learning effects of serious games have been reported in previous research, particularly regarding effects on perceptions of risks and efficacy? and (5) What is the effect of a role-playing simulation game on the risk and efficacy perceptions associated with climate tipping points? These research questions are answered by reviewing literature (sub questions 1,2 and 4), by analyzing results of an online survey among professionals that are actively working on climate change (sub question 3) and investigating the effects of a role-playing simulation game on risk and efficacy perceptions of climate negotiation participants (sub question 5).

The current research builds on previous research on the role of perceptions of risk and efficacy in decision-making processes regarding climate change. This research specifically addresses the knowledge gap regarding perceptions of climate tipping points. Moreover, the currently understudied risk and efficacy perceptions of climate negotiation participants and other climate change professionals are explored. These insights might be valuable for risk communication and management in the field of climate change and other environmental risk domains. This research further contributes to the understanding of the potential uses and effects of serious games in general and in environmental governance in particular. With respect to sustainable development, this research provides insights in the use and communication of scientific research in global climate change governance. Particularly the use of role-playing simulation gaming for experimentation and imagination of climate futures is explored, contributing to the understanding of its potential as a science-policy interface. This is of high relevance because of the current science-policy gap in climate change governance, leading to suboptimal decisions in global climate governance (Haug, Huitema, & Wenzler, 2011; Milkoreit, 2015). The present research will contribute to the understanding of how a science-policy interface can be designed that supports decision-making in environmental governance, which is often faced with complex systems and high levels of uncertainty.

In the theoretical framework that follows, some scientific background on climate tipping points and the answers on the first three sub questions will be discussed. First the risks and uncertainty involved in climate tipping points and their role in climate negotiations will be discussed (section 2.1). Subsequently, the role of cognition in global climate governance is discussed and in particular political implications of changes in risk and efficacy perceptions (section 2.2). In section 2.3, it is explained how the perceptions of climate tipping points can be understood in the broader context of perceptions of climate change risks and perceived efficacy of responding to those risks. In answering the fourth sub question, research on learning effects of serious games including climate change games will be discussed and how this might change perceptions (section 2.4). The results section reveals answers to the third and fifth sub questions.

2. Theoretical framework

2.1 Climate tipping points

2.1.1 Tipping elements, uncertainty and impacts

As defined by Lenton (2011), "A climate 'tipping point' occurs when a small change in forcing triggers a strongly nonlinear response in the internal dynamics of part of the climate system, qualitatively changing its future state" (p.201). Lenton et al. (2008) identified various 'tipping elements' that may switch from one stable state to another stable state during this century; the Greenland ice sheet, Arctic summer sea ice, , Atlantic thermohaline circulation, El Niño/Southern Oscillation, Indian summer monsoon, West-African Monsoon, Amazon rainforest and Boreal Forest Shift/Dieback. In addition, scientists argue that coral reefs have already passed a tipping point as bleaching events cause die-off of reefs worldwide, from which recovery is unlikely (Bruno et al., 2007; Meissner, Lippmann, & Gupta, 2012). Climate tipping points pose serious threats to human wellbeing due to the irreversible and catastrophic impacts (Cai et al., 2013; Lontzek et al., 2015), including intense sea level rise, ecosystem degradation and large shifts in precipitation patterns causing severe droughts (Lenton et al., 2008). Since the likelihood of passing climate tipping points increases with global temperature increase, scientists therefore stress the urgency of strong mitigation action (Cai et al., 2016; Lenton et al., 2008; Schellnhuber et al., 2016).

However, due to the large degree of uncertainty in the climate system, the likelihood of passing tipping points is difficult to estimate (Kriegler, Hall, Held, Dawson, & Schellnhuber, 2009). Moreover, the magnitude of negative impacts remains unclear as well as the time periods over which the impacts unfold (Lenton, 2011). Uncertainties arise not only from variability within climate system itself, but also from human forces including socio-economic, technological and geopolitical drivers, which complicates assessing the actual threats of tipping points (Bosetti et al., 2017; Kopp, Shwom, Wagner, & Yuan, 2016; Lontzek et al., 2015). However, because of the potentially disastrous impacts on human wellbeing, there is general consensus that further global warming should be avoided as much as possible. Even within the 2°C Paris range, it is likely that some tipping points are passed, including coral reefs, the West Antarctic Ice sheet and Arctic summer sea ice (Lenton & Ciscar, 2013; Schellnhuber et al., 2016). Moreover, multiple climate tipping points might interact in which passing certain tipping points increase the likelihood of passing others as well, leading to cascading effects (Cai, Lenton, & Lontzek, 2016). On top of that, some tipping points might result in additional release of GHGs in the atmosphere, such as CO_2 release due to loss of rainforest in the Amazon (Cox et al., 2004) and release of CO_2 and CH_4 due to unfreezing permafrost in Arctic regions (Schuur et al., 2015).

2.1.2 Role of climate tipping points in global climate governance

The notion of abrupt climate change has received growing political and scientific attention (Galaz, Biermann, Crona, et al., 2012) and climate tipping points are an emerging topic in climate science specifically. Climate tipping points are closely linked to the 'planetary boundary' concept, which are boundaries of the "safe operating space" of humanity regarding their interaction with the Earth system (Rockström et al., 2009). A planetary boundary is not exactly the same as a tipping point; planetary boundaries represent the ends of the safe operating space, which are positioned well before the actual threshold (tipping point), taking into account uncertainty of the location of this threshold as well as the time society needs to respond (Steffen et al., 2015). However, as argued by Biermann (2012), "Despite some differences in approach, perspective and research trajectory, all of these notions of planetary boundaries, guardrails, tipping points and critical transitions come down to the same basic idea; the attempt at a quantified identification of the boundaries of the safe operating space of humankind on earth." (p.5). As argued by Biermann (2012), the safe operating space suggested by the planetary boundaries approach leaves room for a variety of political decisions and systems and diversity in possible socio-economic pathways. Thereby, the planetary boundaries are not specific guidelines, but define a 'target corridor' which should be placed in the broader context of sustainable development (Biermann, 2012). According to Galaz, Biermann and Crona et al. (2012), the planetary approach poses multiple complex challenges to global environmental governance: the interaction between science and policy (particular differences in risk perceptions and interests), the role of global policies in supporting of integrated innovations, international institutions' capacity in coping with (interacting) planetary boundaries and the role of international organizations. The first challenge particularly relates to the current study; differences between nations' vulnerability and needs for developments might result in differences in risk perceptions and economic interests, which in turn complicates reaching political agreements (Galaz, Biermann, Crona et al., 2012).

Although planetary boundaries are normatively neutral in the sense that they represent scientific hypothesis about the Earth system, the interpretation of boundaries by political actors is not (Biermann, 2012). Therefore, Biermann (2012) argues that this approach should not be seen as a purely scientific but a political matter as well. In particular, because the planetary boundaries concept highlights the risks associated with exceeding critical thresholds of the Earth system, this is believed to emphasize the urgency of political action (Biermann, 2012; Galaz, Biermann, Folke, Nilsson, & Olsson, 2012). Some scholars have even labeled this planetary boundaries or threshold approach as 'strongly normative' (Galaz, Biermann, Crona, et al., 2012), a 'paradigm shift' (Gardiner, 2009) or as a 'generative metaphor' that restructures or frames information in a particular way that influences perceptions of climate change (Russill & Nyssa, 2009). As pointed out by Galaz, Österblom, Bodin, and

Crona (2016), the increased sense of urgency could trigger the development of global networks and shifts in international institutions. In contrast, Gardiner (2009) argued that increased awareness of tipping points might also undermine rather than motivate political action. Notwithstanding the potential political implications, it is largely unknown how the global climate governance community actually perceives and responds to climate tipping points (Galaz et al., 2016). Given the possible catastrophic impacts on human wellbeing and complex governance challenges involved, political attention of climate tipping points is highly important.

However, the issue of climate tipping points remains largely neglected in global climate negotiations (Milkoreit, 2015). The political debate within climate negotiations is primarily centered around the 1.5 and 2°C goals, although climate tipping points are closely linked to these goals (Schellnhuber et al., 2016). According to Milkoreit (2013; 2015) the problem may lie in cognition, because climate tipping points are not yet sufficiently incorporated in the beliefs systems of climate negotiators (see section 2.2.1). This may in turn be the result of how scientific insights including insights in climate science are communicated (e.g. Barkemeyer, Dessai, Monge-Sanz, Renzi, & Napolitano, 2016) and interpreted (e.g. Budescu, Por, Broomell, & Smithson, 2014). Regarding the vital importance of appropriate governance responses, there is an urgent need for strategies to improve the understanding of climate tipping points, their relationship with global temperature goals and associated governance challenges within the climate negotiation community (Milkoreit, 2015).

2.2 Cognition and decision-making in response to climate tipping points

2.2.1 Cognition in global climate governance

Cognition can be understood as "processes of knowing, including attending, remembering, and reasoning" (Gerrig & Zimbardo, 2002, p. 280). Because of the large impact of collective behaviors on climate change, there is a growing amount of psychological literature focusing on cognitive drivers and barriers to climate change action (Gifford, 2011; Swim et al., 2009). Because decisions in global climate governance are rooted in cognition as well, a cognitive perspective serves as theoretical and empirical basis for understanding decision-making and political behavior (Milkoreit, 2017). However, except from studies by Milkoreit (2013; 2015; 2017) and a few others, this cognitive perspective as well as the role of emotion in climate change politics remains largely unexplored.

Milkoreit (2013) studied the role of cognition in international climate politics, taking a wider perspective on cognition, including not only individual cognitive processes but also social factors and political behavior. By studying belief systems of participants of UNFCCC negotiations, she found that multiple cognitive elements and processes are underlying cooperation in climate change politics

(Milkoreit, 2013). Although the use of climate science can be considered important for optimal decision-making in international climate negotiations, Milkoreit (2015) found some critical cognitive limitations in this regard: "(1) most negotiation participants use a very basic and limited set of insights about climate change that has not changed significantly for a long time, (2) that recent scientific concepts – most notably the idea of climatic tipping points – are not yet part of most diplomats' belief systems; and (3) that hardly any negotiator is able to imagine qualitatively different long-term futures that have been affected by climate change, and link present decisions to those possible futures." (p. 109). She describes this as a 'science-politics disconnect', which is problematic because science-based problem definitions and solutions are crucial in global climate governance (Milkoreit, 2015). Additional support for this science-politics disconnect comes from recent research by Bosetti et al. (2017), who found that policymakers at COP21 failed to update their beliefs in response to climate model forecasts, giving more weight to their prior beliefs and anchored their probability estimates accordingly. Apart from knowledge, Milkoreit (2017) studied additional concepts in belief systems of negotiation participants that are underlying decision-making, including risk perceptions and the sense of agency (which is closely linked to perceived efficacy, see section X), which will be elaborated on in the next paragraph.

2.2.2 The role of perceptions of risks and efficacy in global climate negotiations

Risk perception is concerned with the perceived seriousness and likelihood of negative events and perceived efficacy is the belief in the capability to perform certain actions (see section 2.3). Perceptions of risks and efficacy are important determinants of individual and collective action in response to climate change risks (Heath & Gifford, 2006; Koletsou & Mancy, 2011; Swim et al., 2009). Both psychological constructs are relevant to consider among actors of global climate negotiations, because of their potential influences on political decisions. The perception of the risks associated with passing climate tipping points by climate negotiation participants might influence their sense of urgency of collective efforts in pursuing the 1.5°C or 'well below' 2°C. However, it is doubtful that risk perceptions will have any influence political decision-making without a belief that decisions will have any impact on the likelihood of avoiding or triggering tipping points. Global climate negotiations reflect a social dilemma situation in which individual (national) and collective (global) interests and goals exist and may conflict. In social dilemma situations, collective efficacy (i.e. the shared belief of the ability to achieve collective goals) and individual or self-efficacy (i.e. belief in own actions to achieve collective goals) are important determinants of success in achieving collective goals (Bandura, 2000; Koletsou & Mancy, 2011). In global climate negotiations, the perception of efficacy or agency (see section X) is reflected in selecting and pursuing goals, such as the 2°C and defining pathways to reach these goals (Milkoreit, 2017).

Milkoreit (2017) studied perceptions of risks and agency among participants of global climate negotiations and found that motivation for climate action was larger when considering climate change risks to the negotiators' own country and culture rather than different countries and cultures and when threats are seen as immediate rather than happening in the future. Representatives of vulnerable countries such as island states perceived existential threats concerning their own states as opposed to solely economic threats for developed countries. Existential threats, identity loss and human suffering aroused strong emotions and raised the question of how this can be avoided rather than whether or which impacts should be avoided (Milkoreit, 2017). Furthermore, negotiation participants who already experience climate change impacts in the present had a stronger sense of urgency of climate change action compared to participants who perceived those as future risks (Milkoreit, 2017). However, as Milkoreit (2017) argues, one should not simply conclude that participants from developed countries lack the sense of urgency perceived by participants from vulnerable developing countries, because some participants from developed countries showed similar levels of concern and urgency compared to participants from developing countries. Thus, risk perceptions of climate change impacts among negotiation participants are influenced by other factors as well (Milkoreit, 2017). With regard to agency, Milkoreit's (2017) findings suggested that most negotiation participants were relatively pessimistic about the effectiveness and of the UNFCCC process and the likelihood of achieving the 2°C goal. Participants were not able to think of reasonable pathways towards this goal and were therefore pessimistic about achieving the 2°C goal. This might have to do with the fact that commitments of countries in the Copenhagen Accord in 2009 were not legally binding (Milkoreit's data was from 2012). However, study participants remained optimistic about the collective ability of humanity to solve the problem of climate change (Milkoreit, 2017). Multiple underlying factors may influence agency-related beliefs of climate negotiators, including uncertainty, causal beliefs, perceived resource and power, available scientific knowledge and availably technology (Milkoreit, 2017). Apart from these findings, it is still largely unknown how participants of global climate negotiations perceive risks and efficacy regarding (governance responses to) climate tipping points and how this affect decision-making, which will be investigated in the current study. The next paragraph will elaborate on research on collective decision-making processes in response to climate tipping points.

2.2.3 Collective decision-making to avoid climate tipping points

Negotiating on investments to avoid climate tipping points can be approached as a 'collective risk social dilemma', that not only involves a conflict between individual interests and interests of the group, but also between short-term and long-term interests (Milinski, Sommerfeld, Krambeck, Reed, & Marotzke, 2008). Barrett and Dannenberg (2012) approached climate negotiations as prisoner's dilemma and performed multiple experiments that indicated that when the threshold of 'dangerous climate change' is known, this promotes collective action and groups successfully avoid the threshold. In a later study, Barrett and Dannenberg (2014) developed a game-theoretic model of countries' decisions to reduce greenhouse gas emissions to avoid climate tipping points. They found that below a certain uncertainty threshold, collective action is likely to fail, leading to crossing tipping points (Barrett & Dannenberg, 2014). On the contrary, "…when uncertainty about tipping points is small, the fear of crossing it serves as an effective deterrent" (Barrett & Dannenberg, 2014, p. 39). This suggest that collective action in climate negotiations might be promoted through reducing uncertainty about thresholds of climate tipping points. With regard the uncertainty in thresholds, Lenton (2014) argues scientific effort is needed to improve early warning signals to better predict the proximity of climate tipping points. Reducing uncertainty of thresholds could provoke a 'social tipping point' in which countries successfully cooperate to avoid climate tipping points (Lenton, 2014). However, in reality this early warning might not be early enough due to climate variability, which suggests that strategic enforcement mechanisms are necessary (Barrett & Dannenberg, 2014; Lenton, 2014). Moreover, in the game-theoretic experiments it is assumed that avoiding tipping points is feasible (Barret & Dannenberg, 2014), whereas in reality scientific insights suggest we might have already crossed thresholds of multiple tipping elements (e.g. coral reef dieback), which means governance responses need to include adaptation as well. On top of that, understanding social change in terms of social tipping points may be too simplistic, because this view ignores the many social, cultural, economic and political reasons underlying decision-making (Nuttall, 2012). In addition, there may be other factors that influence cooperation. For example, inequality in resources and vulnerability to climate change risks tends to decrease cooperation in collective risk social dilemmas (Burton-Chellew, May, & West, 2013; Tavoni, Dannenberg, Kallis, & Löschel, 2011).

2.3 Theory on perceived risk and efficacy

2.3.1 Risk perception

2.3.1.1 Definition and theory

Technically, risk can be understood as the quantitative combination of the likelihood and negative consequences of an event. Although risk assessment is a well-known method to evaluate potentially hazardous events or technologies, it has become increasingly clear that people have difficulty relating abstract risk messages and rely much more on intuitive judgments of risks, known as risk perception (Slovic, 1987). Risk perception has been studied by various fields of research, which has resulted in a multitude of conflicting theories and perspectives (for an overview, see Wildavsky & Dake, 1990). Within risk perception literature, two prominent lines of research can be identified: the cultural paradigm and the psychometric paradigm. According to the Cultural Theory of Risk (Douglas & Wildavsky, 1983), perception of risks arises from idealized cultural biases or 'ways of life', that are ideologies about patters of social relations. The psychometric paradigm is mainly concerned with cognitive and affective dynamics including decision-making processes, mental strategies and cognitive heuristics in relation to risk perceptions (e.g. Loewenstein, Weber, Hsee, & Welch, 2001; Sjöberg, 1998; Slovic, 1987; Slovic et al., 2004; Weber & Milliman, 1997). The cultural and psychometric paradigms were later combined in the 'cultural cognition of risk' hypothesis (Kahan, Jenkins-Smith, & Braman, 2011), explaining that similar psychological mechanisms in response to risks can result in different risk perceptions because of underlying cultural worldviews.

There seems to be little scientific consensus about the meaning of risk perception and how it should be measured (Helgeson, Van der Linden, & Chabay, 2012). Perceived risk, worry and concern are often used interchangeably in risk perception literature (Helgeson et al., 2012). However, a critical distinction between perceived risk and concern is that the former refers to information processing of characteristics of the risks, whereas concern involves psychological responses to risks (Reser & Swim, 2011). Moreover, risk perception should not be confused with worry, the latter representing an active emotional experience (Slovic, 1987). In the current research, risk perception is understood as the perceived seriousness and likelihood of negative events, in this case of triggering climate tipping points. Risk perceptions are relevant to study because this influences people's motivation to avoid, adapt to, mitigate or ignore risks (Heath & Gifford, 2006; Leiserowitz, 2006; Milfont, 2012; O'Connor, et al., 1999; Swim et al., 2009; Wachinger, Renn, Begg, & Kuhlicke, 2013). The perception of risks depends on the type of risk, the (social) context of the risk and individual characteristics (Wachinger et al., 2013).

In the environmental domain, research has primarily focused on risk perceptions of natural hazards, such as flood risks (e.g. Brody, Zahran, Vedlitz, & Grover, 2008; Spence et al., 2011;

Whitmarsh, 2008), volcanic hazards (e.g. Barberi, Davis, Isaia, Nave, & Ricci, 2008; Bird, Gisladottir, & Dominey-Howes, 2010) and seismic risks (Armaş & Avram, 2008; Paul & Bhuiyan, 2010). A growing amount of research has also focused on the perception of climate change risks. An important findings is that people tend to perceive climate change risks as psychologically distant, affecting other people in the future and other locations (Maibach, Roser-Renouf, & Leiserowitz, 2008; Spence, Poortinga, & Pidgeon, 2012). Therefore, people generally don't view climate change as an immediate threat and find it less important compared to other societal issues (Leiserowitz, 2005). The uncertainty involved in climate change risks plays an important role in this, as it decreases the perception of the risks being urgent, serving as justification of inaction (Mabey et al., 2011; Swim et al., 2009). Moreover, uncertainty about one aspect of climate change might spread to other aspects as well (Spence et al., 2012). Spence et al. (2012) introduce this phenomenon as 'uncertainty transfer' where increased uncertainty about the causes of climate change may for example increase uncertainty about its impacts. Furthermore, people respond differently to personal vs. societal climate change risks, as personal risks are generally rated higher and probability is more likely to be ignored (Leiserowitz, 2005; Stevenson et al., 2015).

Climate change risk perception has been particularly studied among the public and research suggests this is associated with various individual mitigation behaviors (Bostrom, Morgan, Fischoff, & Read, 1994; Heath & Gifford, 2006; Hidalgo & Pisano, 2010; Leiserowitz, 2006; O'Connor, Bord, Yarnal, & Wiefek, 2002). However, Wachinger et al. (2013) argue that the relationship between risk perception and personal actions is relatively weak. Wachinger et al. (2013) propose three explanations for this 'risk perception paradox' based on their literature review: (1) people accept the risk because the perceived benefits of not taking action outweigh the perceived costs, (2) people don't perceive any agency over their actions and (3) people have limited resources to take action. The second and third explanations is in line with research emphasizing the role of perceived efficacy (i.e. the belief in one's own capability to perform certain behavior) in taking climate change action, which is related to available resources (lack of resources diminishes perceived efficacy). Heath & Gifford (2006) for example showed that perceived efficacy was a strong predictor of behavioral intentions to take personal actions to mitigate climate change. Before going into detail about perceived efficacy (see paragraph 2.3.2), the following paragraph will first elaborate on the perception of risks associated with climate tipping points specifically.

2.3.1.2 Perception of risks associated with climate tipping points

AS Lenton (2008) argued, "Society may be lulled into a false sense of security by smooth projections of global change" (p. 1792). Gradual increase in global temperature may thus be perceived as less serious compared to abrupt and irreversible changes. However, there is a lack of research on how people actually perceive the risks associated with abrupt climate change (Bellamy & Hulme, 2011). One study by Lowe et al. (2006) focused on the effects of the film The Day After Tomorrow (which shows abrupt and catastrophic climate change) on concern, perceived likelihood, responsibility and motivation to take action. The film increased awareness of climate change and motivation to take action, but participants perceived abrupt impacts as impossible or very unlikely (Lowe et al., 2006). A second study by Bellamy and Hulme (2011) compared concern about tipping points versus climate change in general. Perceived likelihood and seriousness of eight tipping elements as defined by Lenton (2008) were investigated. Respondents were concerned about both abrupt climate change and climate change in general, although slightly *less* concerned about abrupt climate change compared to climate change in general (Bellamy & Hulme, 2011). Two important themes emerged regarding perceptions of abrupt climate change; societal and temporal vulnerabilities (Bellamy & Hulme, 2011). With regard to societal vulnerabilities, perceived danger or fear was related to perceived proximity of the impacts of climate change, perceiving developed countries as safe in contrast to developing countries (Bellamy & Hulme, 2011). Secondly, most participants perceived abrupt changes as temporally distant, happening in the long-term future far beyond their own lifetime (Bellamy & Hulme, 2011). This indicates psychological distancing (Spence et al., 2012) of climate tipping points in the social/spatial as well as the temporal dimension.

A further analysis by Bellamy and Hulme (2011) of the underlying reasoning of these perceptions revealed four reoccurring themes; (1) scientific uncertainties (which was given as reason to be concerned as well as a reason to be concerned), (2) catastrophe (the catastrophic nature of abrupt climate change), (3) helplessness (which was linked to catastrophic impacts by some whereas others linked this to uncertainties of risks) and (4) justice/equity (beliefs about impacts on future generations or responsibility of the causes of climate change). In their study, Bellamy and Hulme (2011) the discourse of fatalism dominated the discussions around abrupt climate change. Therefore, they argue that communication in terms of abrupt climate change might be counterproductive because this might create fear about the future, resulting in discourses of fatalism and weakening people's belief in climate change solutions.

2.3.1.3. Factors underlying risk perception

The perception of climate change risks is complex and influenced by many factors including knowledge, affect, values, imagery, personal experience and socio-cultural influences (Leiserowitz, 2006; Van der Linden, 2015). Because the perception of the risks associated with climate change involves an evaluation of their probability and severity, it can be argued that a certain level of knowledge is necessary (Van der Linden, 2015). A positive association seems reasonable, as information about climate change might make people think more about the issue which makes previously unnoticed risks more salient (Milfont, 2012). Indeed, multiple researchers found a positive relationship between knowledge about climate change and perceived risk (Hidalgo & Pisano, 2010; Milfont, 2012; Sundblad, Biel, & Gärling, 2007; Tobler, Visschers, & Siegrist, 2012; Van der Linden, 2015). However, other researchers found that more informed people are *less* concerned about climate change (Kahan et al., 2012; Kellstedt, Zahran, & Vedlitz, 2008). An explanation for these contrasting results might be that researchers fail to recognize differences between different types of knowledge (Kaiser & Fuhrer, 2003). Indeed, knowledge about the causes and impacts of climate change are related with risk perception, rather than physical knowledge (Shi, Visschers, & Siegrist, 2015; Tobler et al., 2012). Furthermore, Van der Linden (2015) found that knowledge predicts perceived risk to society rather than personal risk. Other factors might influence this relationship as well, including trust in scientists and political orientation (Malka, Krosnick, & Langer, 2009).

In addition, the role of emotion or affect in risk perception is an object of discussion among researchers. Prominent theories are the 'risk-as-feelings hypothesis', which posits that decision-making in response to risks results from emotions fear and anger (Loewenstein et al., 2001) and the 'affect heuristic', which postulates that mental representation of the risk induces positive or negative feelings (i.e. affect), which influences decision-making (Finucane, Alhakami, Slovic, & Johnson, 2000; Slovic & Peters, 2006; Slovic, et al., 2007). Both theories are based on dual processing theory, which emphasizes the existence of two separate information-processing systems in decision-making: one that fast, associative and intuitive (i.e. affective processing) and one that is slow, conscious and requires deliberate control (i.e. cognitive/analytical processing) (Chaiken & Trope, 1999; Epstein, 1994; Kahneman & Egan, 2011). From this perspective, analytical ('slow') consideration of the seriousness indicates that high concern is most appropriate, but a ('fast') signal from the affective system is missing, resulting in lower concern than desirable (Weber, 2006). Another view is that emotions serve as "sources of ethical wisdom" (p. 188) which inform moral judgments about risks (Roeser, 2010). Sjöberg (1998; 2007) has questioned the role of emotion or affect in risk perceptions and argues emotion and affect are often measured in very different ways by researchers, leading to contrasting results. Regarding climate change risks specifically, numerous researchers indicate that affect, a more subtle form of emotion, is an important predictor of risk perception (Leiserowitz, 2006; Smith & Leiserowitz, 2012; Sundblad et al., 2007; Van der Linden, 2015). Nevertheless, differences in types of emotions should be taken into account (Sjöberg, 2007) as well how these might influence different types of climate change risks. As found by Stevenson et al. (2015), affective responses were particularly induced by climate change risks to humanity as opposed to risks to non-humans. Milkoreit

(2017) investigated risk perceptions among participants of international climate negotiations and found similar results. Negotiation participants generally lacked concern about risks to non-human life such as environmental degradation and loss of species (Milkoreit, 2017). In addition, particularly climate change risks in the form of existential threats, human suffering and identity loss aroused strong emotions whereas economic and material losses were associated with much weaker emotions and more rational reasoning (Milkoreit, 2017).

A third underlying factor of climate change risk perception is direct experience with the impacts of climate change (Akerlof, Maibach, Fitzgerald, Cedeno, & Neuman, 2013; Reser & Swim, 2011; Spence et al., 2011; Wachinger et al., 2013). People that are directly experiencing the impacts of climate change, such as flooding, perceived climate change as more likely and showed higher concern about climate change impacts (Spence et al., 2011). This experience is particularly related to personal risk perception (i.e. threat to themselves and their local area) of climate change, rather than perceived national risks or risks to society (Demski, Capstick, Pidgeon, Sposato, & Spence, 2017; Lujala, Lein, & Rød, 2015; Van der Linden, 2015). In fact, simply being more vulnerable to climate change risks, such as living close to the coast, might increase perceived seriousness of climate change risks (Brody, Zahran, Vedlitz, & Grover, 2008). The influence of experiencing climate change impacts links to the role of emotion in risk perception, since direct experience involves affective and associative cognitive processes that are much faster and automatic than learning from statistical descriptions (Weber, 2010). Thereby, it seems plausible that direct experience with climate change impacts induces higher concern, which in turn motivates people to undertake climate change action. Although the relationship between flood experience and willingness to take climate change action has been found in some research (e.g. Spence et al., 2011), others found contradictory results (e.g. Whitmarsh, 2008). Therefore, this view might be too simplistic: other factors including perceived efficacy (see paragraph 2.3.2) are important to consider as well.

Furthermore, multiple social-cultural factors influence perception of climate change risks (Van der Linden, 2015). According to the cultural cognition of risk hypothesis, risk perception results from cultural worldviews – attitudes towards social organization on two dimensions: hierarchy-egalitarianism and individualism-communitarianism (Kahan et al., 2011). Findings by various researchers indeed support the influence of cultural worldviews on perception of climate change risks (Akerlof et al., 2013; Kahan et al., 2011; 2011; Shi et al., 2015). Egalitarian Communitarians tend to be more concerned about climate change than Hierarchical Individualists (Kahan et al., 2011; Shi et al., 2015). However, other studies suggest that other factors might be stronger predictors of climate change risk perception (Smith & Leiserowitz, 2012; Xue, Hine, Loi, Thorsteinsson, & Phillips, 2014). With regard to climate tipping points specifically, Bellamy and Hulme (2011) found that egalitarians were more concerned than individualists about abrupt climate change and perceived tipping elements as more likely to happen within the next 50 years. Another explanation of climate change risk perception can be found in value orientations, which are stable guiding principles that are important predictors of environmental attitudes and behavior (Stern, Dietz, Abel, Guagnano, & Kalof, 1999; Stern, Dietz, & Kalof, 1993). Values partly overlap with cultural worldviews conceptually, but differ in two ways; values are guiding principles that are more stable and more specific than values and cultural worldviews follow from values (Stern et al., 1999; Stern et al., 1993, as cited in Van der Linden, 2015). Particularly biospheric values (i.e. nature and biosphere) are positively associated with climate change risk perceptions (Kellstedt et al., 2008; Milfont, 2012; Van der Linden, 2015). In addition, social norms (i.e. socially approved or normally performed actions) influence climate change risk perception (Van der Linden, 2015). Social norms might play an important role in formation of risk perceptions as well as a mediating role in the effect of risk perception on behavior (Lo, 2013). In addition, trust in scientists or experts influences risk perception (Kellstedt et al., 2008; Malka et al., 2009). Contrary to their expectations, Kellstedt et al. (2008) found that respondents with high trust in scientists as well as those with high trust in policy experts showed less concern compared to respondents with low trust. There are also socio-demographic factors underlying risk perception of climate change, including age and gender (Van der Linden, 2015).

In sum, the perception of climate change risks is complex and influenced by many factors. Most research in this field has focused on risk perceptions of climate change in general among the public. No research has yet specifically focused on the perception of risks associated with climate tipping points among participants of UNFCCC negotiations. Although some of the underlying mechanisms may be similar, there might also be some critical differences. For example, climate skepticism might be of less relevant when considering negotiation participants and additional factors such as national interest become important (Milkoreit, 2013). Moreover, climate tipping points involve a high degree in uncertainty in timelines and impacts which might influence risk perception. The current research will be a first attempt of exploring these underlying mechanisms of this specific type of climate change risks among this particular group of people.

2.3.2 Perceived efficacy

2.3.2.1 Definition and theory

Perceived efficacy can be understood as the perceived ability to perform certain actions (i.e. self-efficacy) as well as the belief that those actions have certain desirable outcomes (i.e. outcome expectancies) (Bandura, 1977). Although agency and efficacy are highly related concepts, perceived efficacy can be seen as an agency concept that is focused on the individual and is therefore at the core of human agency (Bandura, 2000). As explained by Milkoreit (2017), "Agency begins in the mind. But agency is ultimately the result of multiple interacting factors, including cognition and affect, other personal factors, resource availability, and environmental events." (p. 163). According to Social Cognitive Theory (SCT), perceived self-efficacy and outcome expectancies determine which actions people pursue and how much effort they put in those actions, which plays a large role in motivation and behavior (Bandura, 1998; 2000). As SCT posits, when self-efficacy is high and outcome expectancies are positive, this leads to action whereas low self-efficacy with negative outcome expectancies lead to inaction (Bandura, 1998). Self-efficacy is similar to the concept of perceived behavioral control, which is an important determinant of behavior according to the Theory of Planned Behavior (Ajzen, 1988; 1991). Apart from self-efficacy, the perceived collective ability to create desired results (i.e. collective efficacy) becomes relevant in collective action situations (Bandura, 2000). This particularly applies to climate change action, where individual actions will only have a small impact on the outcomes and the common goal can only be achieved through large-scale collective action (Koletsou & Mancy, 2011). As stated by Bandura (2000), "people's shared beliefs in their collective efficacy influence the types of futures they seek to achieve through collective action, how well they use their resources, how much effort they put into their group endeavor, their staying power when collective efforts fail to produce quick results or meet forcible opposition, and their vulnerability to the discouragement that can beset people taking on tough social problems" (p. 76). Thus, perceived efficacy plays a central role in individual and collective human agency, through cognitive, motivational and emotional processes (Bandura, 1998). It largely determines the types of goals people pursue; the higher the perceived efficacy, the higher the goals are set and the stronger the commitments to reach these goals (Bandura, 1998). Furthermore, people with strong feelings of efficacy tend to visualize success scenarios that positively guide behavior whereas those with doubts of their efficacy tend to visualize failure scenarios that undermine performance (Bandura, 1998). It also influences causal attributions, as people with high feelings of efficacy tend to attribute failures to insufficient effort whereas people with low feelings of efficacy tend to attribute failures to low ability (Bandura, 1998). With regard to emotional processes, feelings of efficacy also influence emotional responses to stressful or threatening situations and more specifically perceptions of risks (see section 2.3.3).

Both self-efficacy and collective efficacy are important to consider in social dilemma situations, where people pursue individual goals as well as collective goals. As suggested by Koletsou and Mancy (2011), the following efficacy constructs are relevant in the context of climate change action: (1) self-efficacy and outcome expectancies of individual goals, (2) self-efficacy and personal outcome expectancies of collective goals and (3) collective efficacy and collective outcome expectancies of collective goals. The second efficacy construct is in line with the 'efficacy-cooperation hypothesis' (Kerr, 1992), which poses that the higher the self-efficacy to contribute to the collective goal, the higher the probability of cooperation (Kerr, 1989; Kerr & Kaufman-Gilliland, 1997). With regard to collective goals, research has indicated that individuals with high levels of perceived collective efficacy are expected to contribute more to collective goals by engaging in collective action, which increases the likelihood that goals are achieved (Van Zomeren et al., 2008). Thus, both perceived self-efficacy and collective efficacy might be of relevance in the exercise of agency in global climate governance. As previously stated, perceived efficacy might be important in the global temperature goals that are pursued by participants in global climate negotiations (Milkoreit, 2017). Participants who believe in their individual contributions to collective goals and in the collective ability of the climate community to avoid triggering climate tipping points might result in an increased collective effort to mitigate climate change.

2.3.2.2 Factors underlying perceived efficacy

According to Bandura (1998) there are four principal ways in which perceived individual and collective efficacy can be enhanced, of which the most effective way is past experiences of success. Particularly when people overcome obstacles that require effort, feelings of efficacy become strong and people become less likely to be discouraged by failure (Bandura, 1998). Past experience of success can enhance perceptions of efficacy on the individual as well as the collective level, which in turn positively affects group success (Riggs & Knight, 1994). Experiencing group success may shape perceptions of group potency, which is conceptualized as the overall belief in the collective efficacy of a group to be effective in a broad range of tasks and situations (Gibson & Earley, 2007; Gully, Incalcaterra, Joshi, & Beaubien, 2002). In global climate negotiations, this may refer to an overall belief in the UNFCCC as successful cooperation framework for global action to tackle climate change. Past negotiation failures may lead to a loss of feelings of agency, which might hamper the collective ability of the negotiation community to implement cooperative agreements (Milkoreit, 2017). As previously stated in section 2.2.3, Milkoreit (2017) found that negotiation participants were rather pessimistic about the effectiveness and speed of the UNFCCC process but remained optimistic about the humanity's ability to solve climate change. An important factor in this feeling of hopefulness was the experience of past successes in creating institutions such as the Climate Fund (Milkoreit, 2017).

A second important source of perceived efficacy according to Bandura (1998) is 'social modeling'; seeing other people succeed that are similar to oneself. Thirdly, social persuasion by others of one's capability influences perceived collective efficacy; individuals in a group with high levels of collective efficacy might persuade others to contribute as well and thereby create a positive atmosphere in which collective action becomes more likely (Bandura, 1998). A fourth important factor is people's physical or emotional state, on which they rely when judging their efficacy; depressed mood decreases perceived efficacy whereas positive moods strengthens this (Bandura, 1998). On the other hand, efficacy beliefs might also induce emotions. As Milkoreit (2017) established, uncertainty among climate negotiators about whether and how the 2°C temperature goal could be reached resulted in feelings of hopelessness.

Another important factor underlying perceived collective efficacy specifically is social identity, i.e. "socially shared understandings of what it means to be a group member" (Van Zomeren et al., 2008, p. 505). According to the Social Identity Model of Collective Action (SIMCA; Van Zomeren et al., 2008), social identification with a group enhances collective outcome expectancies, which motivates group members to achieve collective goals. SIMCA postulates that high identifiers perceive collective goals as more binding and are intrinsically motivated to achieve these goals whereas low identifiers are more likely to evaluate costs and benefits and are thus more extrinsically motivated to contribute to collective goals (Van Zomeren et al., 2008). Some studies suggest that social identity plays an important role in collective action regarding climate change specifically. For example, social identity has been identified as important motivational pathway to participate in local climate change protection initiatives (Bamberg, Rees, & Seebauer, 2015; Rees & Bamberg, 2014).

Furthermore, since climate change action is dependent on many actors, the level of interdependence between those actors is important. Gully et al. (2002) have shown that in situations with high interdependence, the relationship between team-efficacy and team performance is stronger. In global climate negotiations, there is not only a high degree of interdependence in achieving collective goals, but also in the outcomes and consequences. Moreover, there is a high degree of interdependence in resources, as some countries may not have the necessary resources available to address climate change and tipping points specifically and may depend on resources of other countries. The strong interdependence among actors in global climate negotiations indicates that perceived collective efficacy might be a highly important factor for successful negotiation on climate tipping points. This also touches upon another well-known factor underlying cooperation in collective dilemmas; reciprocal trust (e.g. Kahan, 2003). As Kahan (2003) states "Individuals who have faith in the willingness of others to contribute their fair share will voluntarily respond in kind" (p. 72). In global climate negotiations, trusting other participants on their willingness to contribute to collective goals might enhance feelings of collective efficacy. On the other hand, as Milkoreit (2017) argues, perceiving others as reluctant to contributing might lead to feelings of hopelessness.

With regard to climate change specifically, Kellstedt et al. (2008) found some underlying factors of perceived efficacy and feelings of personal responsibility; age, value orientations, knowledge and trust in scientists. Contrary to expectations, better informed participants and participants with high trust in scientists reported lower levels of efficacy to act on climate change (Kellstedt et al., 2008). This is contrast with findings by Milfont (2012) suggesting a positive relationship between knowledge about climate change and perceived efficacy. Other factors underlying self-efficacy of personal climate change action are value orientations; ecocentrism is positively associated with self-efficacy (Heath & Gifford, 2006). Furthermore, females generally report higher levels of self-efficacy compared to male (Heat & Gifford, 2006). With regard to feelings of efficacy among climate negotiators, Milkoreit (2017) found that, apart from success in creating institutions, recent developments in the private sector, community activities at the local level and beliefs in the possibility of a better future were the most important factors (Milkoreit, 2017). The most dominant factor diminishing their sense of agency was the current negotiation position of the United States (Milkoreit, 2017).

2.3.3 How perceived risk and efficacy influence climate change action

2.3.3.1 The role of perceived risk and efficacy in coping with climate change risks

Risk perception and perceived efficacy are both important factors in coping responses to climate change stressors and the two concepts are interrelated (Milfont, 2012; Swim et al., 2009). As argued by Bandura (1998), “Efficacy beliefs influence how threats are perceived and cognitively processed. If people believe they can manage threats they are not distressed by them; but if they believe they cannot control them they experience high anxiety, dwell on their coping deficiencies, view many aspects of their environment as fraught with danger, magnify possible risks and worry about perils that rarely happen ” (p. 59). In line with this, Breakwell (2010) has argued that a high level of perceived efficacy entails a strong perceived ability to perform actions to protect oneself from potential risks, resulting in lower levels of perceived risk. According to this reasoning, there would be a negative relationship between perceived efficacy and risk perception.

However, various studies have revealed a positive relationship between climate change risk perception or concern and perceived efficacy (Brody et al., 2008; Heath & Gifford, 2006; Kellstedt et al., 2008; Milfont, 2012; Spence et al., 2011). As Brody et al. (2008) explain, people with high levels of self-efficacy of taking action on climate change are more likely to view climate change as serious risk. Indeed, their results suggested that self-efficacy was a strong positive predictor of climate change risk perception (Brody et al., 2008). In addition, Heath and Gifford (2006) found that self-efficacy and the belief that climate change has negative impacts were positively related. Similarly, Milfont (2012) found a positive relationship between concern about climate change and perceived efficacy. According to Hornsey et al. (2015) there are three possible explanations of the positive relationship between perceived efficacy and risk perception: (1) perception of high risk causes high perceived efficacy, (2) high perceived efficacy causes perception of high risk and (3) a third variable positively influences both risk perception and efficacy. Hornsey et al. (2015) found that participants in the group with a high-risk manipulation reported higher levels of collective efficacy compared to the low-risk group, which supports the first explanation. This is line with research by Milfont (2012) who found that the direction of the relationship is from concern to efficacy instead of the other way around, which was based on path models.

Two dominant theories that explain individual responses to risks from risk perception and perceived efficacy are the Risk Perception Attitude framework (Rimal & Real, 2003) and Protection Motivation Theory (PMT; Rogers, 1983). Both theories were originally developed in the domain of health risks, but have been applied more recently to climate change risks. The Risk Perception Attitude (RPA) framework identifies four attitudinal groups based on different levels of perceived risk and efficacy, as shown in Table 1. People with high perceived levels of both risks and efficacy tend to have a responsive attitude; they are most motivated to engage in self-protective behavior, whereas those with low perceived risk and efficacy tend to be the least motivated (Rimal & Real, 2003). Those in the low-risk-high-efficacy group are not motivated by perceived risk, but by their perceived capability to protect oneself and those in the low-efficacy-high-risk group tend to have conflicting motivations (Rimal & Real, 2003). Recently, this framework has recently been applied to studying individual behaviors relating to climate change by Mead et al. (2012) who particularly focused on perceptions of adolescents. Results indicated that individuals with both high perceived risks and high perceived efficacy were most likely to seek information on climate change (Mead et al., 2012). This is in line with research suggesting that negative fearful visualization of climate change might be counterproductive in changing behavior because although this increases perceived risk, it decreases perceived efficacy and thus not motivates action (O'Neill, Boykoff, Niemeyer, & Day, 2013; S. O'Neill & Nicholson-Cole, 2009). Visualizations of positive energy futures on the other hand can increase perceived efficacy (O'Neill et al., 2013).

		Perceived efficacy	
		low	*high*
Perceived risk	*low*	Indifference	Proactive
	high	Avoidance	Responsive

Table 1. Two-by-two matrix of risk responses following perceived risk and efficacy according to the Risk Perception Attitude Framework (Rimal & Real, 2003).

According to Protection Motivation Theory (PMT; Rogers, 1975; Maddux & Rogers, 1983), the motivation to protect oneself from a negative event results from cognitive appraisal of the severity and likelihood of a threat (i.e. risk perception) and the outcome expectancy and self-efficacy of the coping response (i.e. perceived efficacy). Empirical findings suggest that PMT is indeed a valuable model in explaining responses to risks of natural hazards such as flooding (e.g. Bubeck, Botzen, & Aerts, 2012) and earth quakes (e.g. Mulilis & Lippa, 1990) and to responses towards climate change risks in general as well (e.g. Bockarjova & Steg, 2014; Lam, 2015). For example, Mulilis and Lippa (1990) found that persuasive messages that manipulate beliefs about severity and likelihood of earthquakes and perceived effectiveness and capability of earthquake preparedness resulted in changed behavior to prepare for earthquakes. Building on PMT, Grothmann and Patt (2005) developed a model for climate change adaptation, which explains adaptation intention from (1) perceived probability and severity of climate change risks, (2) perceived adaptation efficacy and self-efficacy and (3) perceived adaptation costs. As Grothmann and Patt (2005) explain, perceived adaptation efficacy is the belief that adaptation actions are effective in protecting from harm of the risk, perceived self-efficacy is the belief that the person is capable of carrying out these adaptation actions and perceived costs can refer to any type of costs including time and effort. According to this model, adaptation appraisal (i.e. efficacy and cost perceptions) comes after risk perceptions and only occur when a particular threshold of risk perception is exceeded (Grothmann & Patt, 2005). Similar to the RPA framework, the model predicts that when perceived risks and perceived adaptive capacity are both high, this results in adaptive responses that avoid damage or increase benefits. On the other hand, high risk perception in combination with low adaptation appraisal will result in maladaptive responsive such as denial, fatalism or wishful thinking (Grothmann & Patt, 2005). However, as Grothmann and Patt (2005) argue, adaptation intentions might not always lead to actual adaptation actions, as this depends on other factors including resources, power, knowledge and institutional support.

2.3.3.2 Conceptual model

Based on previous research on perceived risk and efficacy as discussed so far, one may argue that similar factors might be underlying perceptions of risks associated with climate tipping points and perceived efficacy of influencing the likelihood of avoiding climate tipping points. Risk and efficacy perceptions might in turn influence the engagement with climate tipping points in international climate negotiations. Figure 1 shows the conceptual model that was developed based on this literature. However, it is not implied that risk and efficacy perceptions are the only factors influencing engagement and political decision-making in response to climate tipping points, as this is a complex process influenced by many factors and political dynamics. Besides that, the relationships between factors should also not be understood as unequivocal, as factors might influence each other in multidirectional and complex ways. Taking this into account, the conceptual model presents a proposition based on literature on how risk and efficacy perceptions might influence engagement with climate tipping points in international climate negotiations.

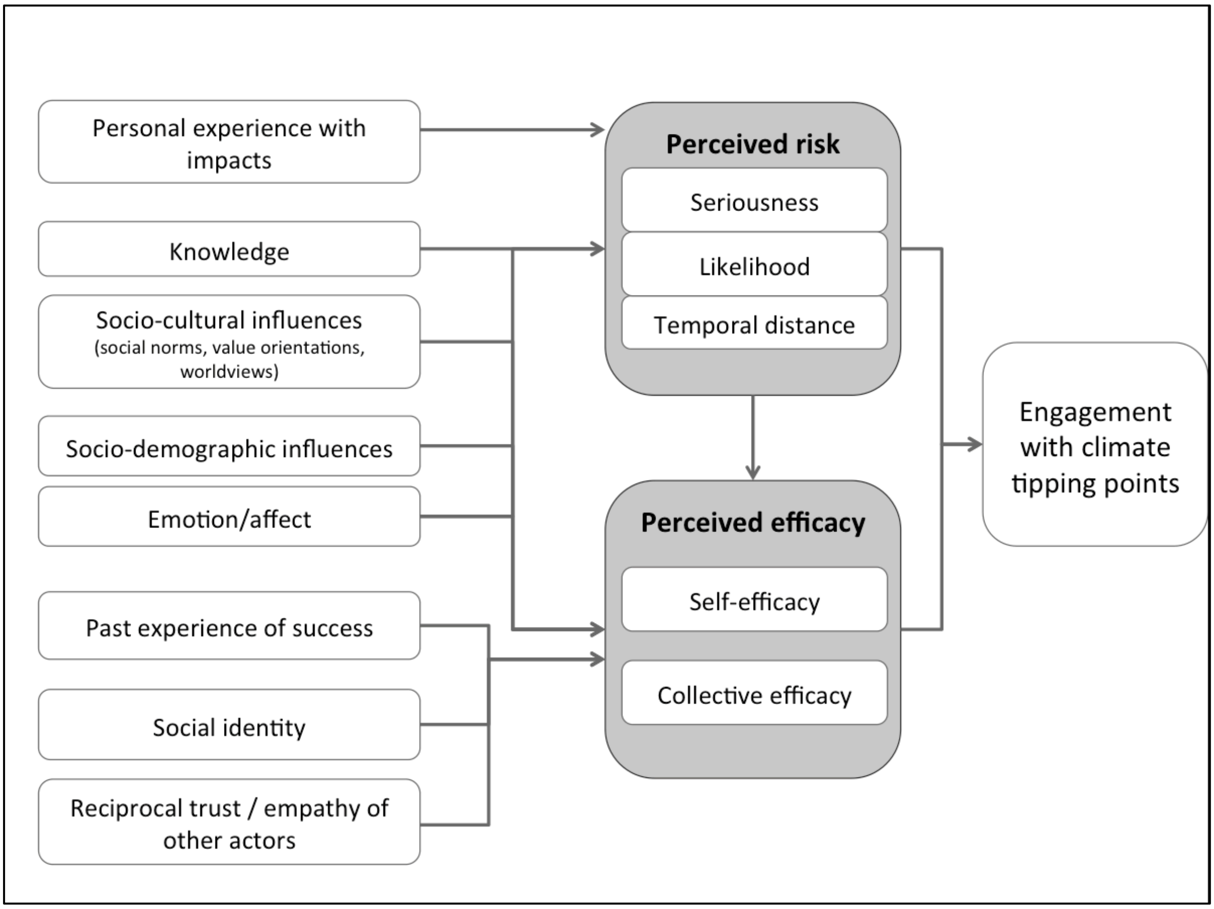


Figure 1. Conceptual model of determinants of the perception of the risks associated with climate tipping points and perceived efficacy of influencing the likelihood of climate tipping points and how this might influence engagement with and political decision-making regarding climate tipping points in international climate negotiations.

2.4 The use of serious gaming to change perceptions of climate change

2.4.1 Theory on learning through serious gaming

The recognition that games can have many more positive effects than leisure only, has led to the development of many 'serious games' over the last decades (Wouters, Van der Spek, & Van Oostendorp, 2009). The term was first introduced by Abt (1970), who defines that serious games "…have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement." (p. 9). Serious games are characterized as being interactive, aimed at a specific goal and including agreed rules and constraints (Wouters, Van Nimwegen, Van Oostendorp, & Van der Spek, 2013). A main advantage of serious gaming as opposed to traditional learning methods is that it provides an experiential learning environment and stimulates motivation. Games have characteristics that intrinsically motivate players by means of challenge, fantasy and curiosity (Malone, 1981), which stimulates the learning process (Prensky, 2003). People that are more intrinsically motivated while learning are also more likely to apply the learning material to other situations (Sitzmann, 2011). In line with constructivist learning theories, serious gaming enables learners to explore the material and actively construct knowledge, which is then integrated into existing mental models (Moreno & Mayer, 1999; Mayer, 1999). Moreover, by actively engaging learners, new information is better integrated with existing knowledge and is more likely to persist on the long term (Wouters et al., 2013). Additional learning advantages of serious games include the simulation of tasks that represent real-world cognitive processes and providing immediate feedback which allows players to correct for mistakes (Wouters et al., 2013). Some researchers have focused on relationship between game attributes and effectiveness in terms of different learning outcomes (e.g. Cameron & Dwyer, 2005; Greitzer, Kuchar, & Huston et al., Wilson et al., 2009

Dieleman and Huisingh (2006) argue that serious gaming is particularly useful for sustainability education because games create shared learning experiences that promotes collaboration and allow to experiment with alternative solutions. In public policy, serious gaming is particularly useful for policy makers to understand complex systems, because simulating the behavior of complex system prior to implementation of policies and regulations allows for anticipation of (unintended) effects (Mayer, 2009). Furthermore, because serious games may provide an overview of possible problems, this may trigger new policy challenges which in turn enables the identification of possible strategies (Mayer, 2009). Multi-actor policy-games are particularly useful, because they allow for exploration of not only technical-physical complexities but social-political complexities as well; who the stakeholders are, what drives them, how much power they have, what the interdependencies between stakeholders are and so on (Mayer, 2009). The role of serious gaming in environmental governance will be further discussed in paragraph 2.4.4. Apart from gaining knowledge, serious games have been used in a variety of areas to change attitudes and behavior (Connolly et al., 2012). The next paragraph will elaborate on empirical findings on the effectiveness of serious games in terms of cognitive, affective and behavioral effects.

2.4.2 Empirical findings of learning effects

With respect to the learning potential of (serious) games, there has been a growing interest in empirical research on the actual effectiveness in terms of learning outcomes (Connolly et al., 2012). Learning effects of serious games can be distinguished in cognitive learning outcomes (including knowledge acquisition, knowledge organization and knowledge development and application such as problem solving), skill-based learning outcomes such as motor skills and affective outcomes (attitudes, motivation and goals) and behavioral outcomes (Connolly et all, 2012; Kraiger, Ford, & Salas, 1993). Multiple meta-analyses indicate that serious games and simulations might be more effective in multiple learning categories compared traditional learning methods (Boyle et al., 2016; Connolly et al., 2012; Vogel et al., 2006; Wouters et al., 2009). With regard to cognitive learning outcomes of games, knowledge acquisition is still most frequently researched (Boyle et al., 2016) and this effect has been established by a vast amount of research in various domains such as engineering (e.g. Papastergiou, 2009), mathematics (e.g. Kebritchi, Hirumi, & Bai, 2010) and health-related knowledge (e.g. Beale et al., 2007; Peng, 2009). However, some researchers found no immediate knowledge gains (Annetta, Minogue, Holmes, & Cheng, 2009; Rondon, Sassi, & Furquim De Andrade, 2013). A possible explanation for these contrasting findings is that knowledge gains of serious games persist over a longer time compared to traditional learning methods and thereby appear only on the long-term (Sitzmann, 2011; Van der Spek, 2011). Another possible explanation is that learning outcomes are often anecdotal and the quality of research designs is often insufficient (Wouters et al., 2013). Indeed, Girard, Ecalle and Magnan (2013) conducted a meta-analysis of only randomized controlled trials (which provides the most robust scientific evidence for effectiveness) and concluded that the amount of experimental evidence is insufficient. On top of that, there are large differences in game design, which might have implications for their effectiveness.

Furthermore, affective and motivational outcomes are broadly referred to as the subjective experiences of games including emotional/affective responses, flow, attitudes and motivation (Connolly et al., 2012). Various affective and motivational learning outcomes of serious games have been found in empirical studies (Connolly et al., 2012), such as attitudinal change (Wouters et al., 2009) and changes in emotions (Granic, Lobel, & Engels, 2014). Changes in beliefs and perceptions could also be placed in this learning category, which will be further explained in section 2.4.3. At last, research has indicated that serious games can be effective in changing behavior, which has been particularly demonstrated in the health domain (Baranowski et al., 2003; Baranowski, Buday, Thompson, & Baranowski, 2008; Peng, 2009). Yet, serious games have also been used to promote various pro-environmental behaviors such as recycling (Centieiro, Romão, & Dias, 2011) and energy saving (Gustafsson, Katzeff, & Bang, 2009). However, it is most likely that serious games induce changes in behavior in an indirect way, through psychological mechanisms and cognitive processes including knowledge, motivation and self-efficacy (Thompson et al., 2010).

2.4.3 The use of serious games to change perceived risk and efficacy

A benefit of serious games is that it more likely increases perceived efficacy of learning the material compared to traditional learning methods and thereby improve learning (Meluso, Zheng, Spires, & Lester, 2012). Self-efficacy may be particularly enhanced when the level of realism in the game is high, as argued by Lakhmani, Sanchez, & Raybourn (2012). Moreover, serious games have shown to increase people's belief in their own capacity of performing certain behaviors (i.e. perceived self-efficacy), such as health-related behavior (Peng, 2008; 2009) and driving (Backlund, Engström, Johannesson, Lebram, & Sjödén, 2008). Simulation games can also improve self-efficacy of dealing with situations that involve risks, although research is rather scarce. For example, Chittaro (2012) found that a serious game improved self-efficacy in coping with an aircraft evacuation. With regard to environmental risks, serious games might be effective in changing perceived self-efficacy to take precautionary actions (Tanes, 2017). Research on the use of serious games to change efficacy perceptions related to responses to climate change and climate tipping points specifically is lacking and will be addressed in the current study. With regard to risk perception, some studies suggests that serious games can change the perception of risks, such as health risks (e.g. Crovato et al., 2016), risks of a terror attack (e.g. Chittaro & Sioni, 2015) and flood risks (e.g. Rebolledo-Mendez, Avramides, de Freitas, & Memarzia, 2009). For example, Rebolledo-Mendez et al. (2009) analyzed the effects of FloodSim, a simulation game in which players take policy decisions that address the risk of flooding in the UK, and found increased awareness of flood risks among participants (Rebolledo-Mendez et al., 2009).

2.4.4 Serious gaming for climate change education and governance

Serious gaming has been recognized as valuable tool in environmental governance, because this provides an interactive learning environment for educating system dynamics, which can support decision-making involving complex systems (Alessi & Kopainsky, 2015). Serious games have been developed in various sustainability fields including energy management, water management, corporate social responsibility, sustainable urban development and climate change management

(Katsaliaki & Mustafee, 2015). Because environmental governance often entails long-term decision-making strategies based on scenarios with future uncertainties and complexities, there is a large potential for simulation games as gaming as scenario development and decision-support tools (Vervoort, Kok, van Lammeren, & Veldkamp, 2010). Role-playing games and simulation games or a combination of the two might be particularly useful in supporting decision-making in environmental governance. As defined by Mayer, Carton, de Jong, Leijten and Dammers (2004), a simulation game is "a simplification and condensation of the real system, allowing participants to experiment safely with (future) decisions and institutional designs and reflect on the outcomes" (p. 314). In this artificial setting, players can learn about the consequences of their decisions, which is particularly relevant in understanding the dynamics of complex systems (Sitzmann, 2011). Therefore, simulation games can be useful for supporting policy and decision-making because scenarios are representations of the future based on models whereas games allow for the exploration of that future in an interactive way (Mayer et al., 2004). The role-play element entails that actors take the role or perspective of other actors and thereby learn about the responsibilities, expectations and views of these actors (Peng, Lee, & Heeter, 2010). This way, actors bring their own belief systems, which are based on values, problem perceptions and interests to the game (Mayer, 2009).

Role-playing (and) simulation games have been developed and studied in various areas of environmental governance, including ecosystem management (e.g. Bousquet et al., 2002), water management (e.g. Bassi et al., 2015; Valkering et al., 2013; Van der Wal et al., 2016), sustainable agriculture and land-use management (e.g. Ducrot, van Paassen, Barban, Daré, & Gramaglia, 2014; Salvini, van Paassen, Ligtenberg, Carrero, & Bregt, 2016; Speelman, García-Barrios, Groot, & Tittonell, 2014) and climate change management (e.g. Rumore et al., 2016; Sterman et al., 2015; Susskind & Rumore, 2013). An often mentioned benefit of these games is that it promotes social learning (Ducrot et al., 2014; Salvini et al., 2016; Van der Wal et al., 2016), which entails "creating mutual understanding and alignment through dialogue and knowledge generation and learning concerning the issue-at-stake" (Ducrot et al., 2014, p. 67), which might enhance collective action. Other benefits are that they support the involvement of stakeholders (Bousquet et al., 2002; Speelman et al., 2014) and they provide valuable insights in future management strategies, adaptation pathways, societal perspectives and actor coalitions (Bassi et al., 2015; Valkering et al., 2013; Van der Wal et al., 2016). Hence, serious gaming might be a valuable tool effective tool for participatory scenario development, in which stakeholders exchange their ideas about future developments and the associated complexities and uncertainties (Vervoort et al., 2010.

In their review of serious games for sustainable development, Katsaliaki and Mustafee (2015) found that a majority focused on climate change. In an overview, Reckien and Eisenack (2013) analyzed more than 50 climate change games that ranged from board games to role-plays to digital games. Climate change games can have many benefits, such as that they allow for experiential learning that is active rather than passive, which makes the players more readily absorb information (Ouariachi, Olvera-Lobo, & Gutiérrez-Pérez, 2017). Moreover, they might be effective in overcoming self-fulfilling prophecies resulting from the uncertainty involved in climate change (Van Pelt et al., 2015). Furthermore, players can experiment with situations that they are unfamiliar with and envision being in the future, which makes them aware of future impacts of decisions (Ouariachi et al., 2017; Wu & Lee, 2015). Thereby, players are provided with a level of control over the climate system that they normally don't have and are provided a 'safe space' which allows for experimentation with options and impacts that are not experienced in the real world, at a relatively low cost (Rumore et al., 2016; Schenk & Susskind, 2014). This is particularly useful for the perception of risks associated with climate tipping points, that are characterized by large uncertainties and a long time scope. Furthermore, role-playing simulation games can uncover climate risk decisions, increase awareness of those risks and promote collective action (Mendler de Suarez, Suarez, & Bachofen (2012). Despite the overwhelming potential of the effects of role-playing simulation games in changing knowledge and beliefs of climate change, there is still a lack of research on their actual effectiveness (Ouariachi et al., 2017; Rumore et al., 2016). A few researchers have addressed this, which will now be discussed.

Some researchers have reported learning effects of role-playing exercises to support climate change risk management in coastal communities (Schenk & Susskind, 2014; Susskind & Rumore, 2013; Rumore, 2015; Rumore et al., 2016). Results suggested that this increased awareness and concern of climate change risk (Rumore, 2015; Rumore et al., 2016), increased belief confidence in the community to take action (Susskind & Rumore, 2013), a better understanding of the complexity of climate change and how this relates to adaptation and increased empathy for perspective of others (Rumore et al., 2016). Furthermore, research on a role-playing simulation game that specifically resembles international climate negotiations (WORLDCLIMATE; Sterman, 2015) also indicated improved knowledge about climate change. In addition, players were more worried about global warming, more likely to recommend to take early actions and showed greater willingness to take pro-environmental actions (Sterman, 2015). This indicates that role-playing simulation games might be effective in changing knowledge and perceptions regarding climate tipping points. So far, no research has investigated this and it will be the focus of the current study.

2.4.5 Conceptual model of the effects of a role-playing simulation game on changing perceived risk and efficacy of climate tipping points

Building on the previously described literature, a conceptual model was created on how a role-playing simulation game about climate tipping points could change risk and efficacy perceptions of climate negotiation participants, which might in turn affect their future interactions within their engagement with climate tipping points (see Figure 2). Previous research has indicated that serious games have cognitive and effects including knowledge gains and changes in emotions. These are underlying factors of perceived risk and efficacy. A serious game about climate tipping points might thus be effective in improving knowledge regarding this issue and induce emotional responses, which in turn influences perceived risk and efficacy. Furthermore, an imaginary personal experience with climate tipping points might be induced by a serious game, for examples by narratives or visualizations of possible impacts of tipping points or by imagining what the impacts could be, which in turn could affect perceived risk and efficacy. In addition, a role-playing simulation game that shows impacts of collective decisions on the likelihood of triggering climate tipping points. Success or failure of collective action in the game in avoiding tipping points might influence their perceived collective efficacy. Moreover, through interaction with other participants, they might become more aware of perspectives and mandates of other countries, which might enhance reciprocal trust and empathy. This might in turn also affect the perceived collective efficacy to avoid climate tipping points. Besides that, the role-playing game might also change perceptions of risk and efficacy directly, based on previous research (see section 2.4.3). In section 3.2, the elements of the role-playing simulation game that was developed in the Gaming Climate Futures project is described in more detail and the types of cognitive/affective effects are further explained.

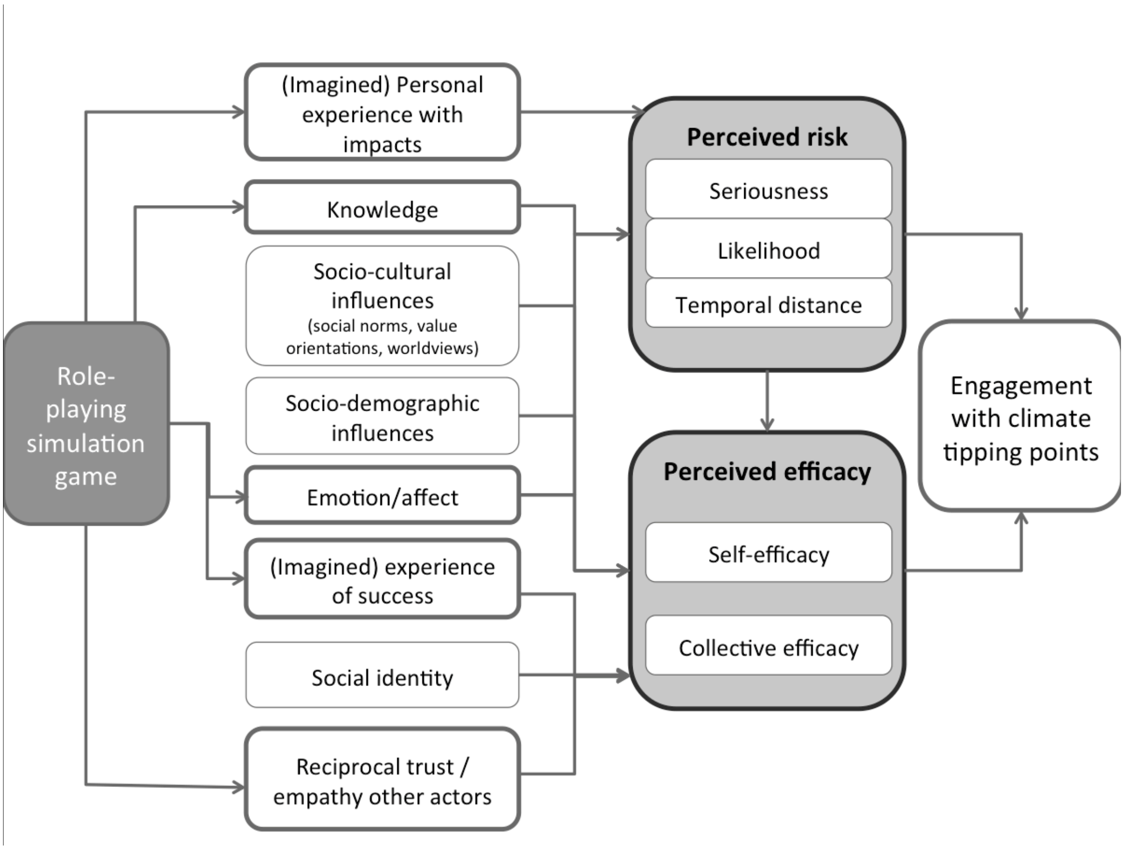


Figure 2. Conceptual model of how the role-playing simulation game might change perceived risk and efficacy regarding the risks of climate tipping points and engagement with climate tipping points in global climate negotiations.

3. Hypotheses

The previous paragraphs provided answers on sub questions 1,2 and 4 by elaborating on relevant literature. Although research on perceptions of climate tipping points is still lacking, some hypotheses can be formulated regarding perceived risk and efficacy of climate tipping points among climate negotiation participants and how the role-playing simulation game might influence these perceptions.

3.1 Hypotheses on perceived risk and efficacy

Based on previous research on risk perceptions of climate change and perceptions of abrupt climate change specifically, some hypotheses can be formulated on the perceptions of participants of UNFCCC negotiations and other climate change professionals. Bellamy and Hulme's (2011) findings suggested that people are generally concerned about climate change in general as well as abrupt climate change. Therefore, at least a moderate level of concern about climate tipping points can be expected. Furthermore, previous research has indicated that climate change risks are generally perceived as more likely affecting other countries compared to people's own country (Maibach et al., 2008; Spence et al., 2012). More specifically, research by Bellamy and Hulme (2011) indicated that this distance is also perceived when considering effects of climate tipping points. Therefore, this perceived spatial distance is also expected in the current study. Based on Bellamy and Hulme (2011), it is expected that the impacts of climate tipping points are perceived as distant in the temporal domain as well: happening in the long-term rather than the short-term future. In addition, based on research suggesting that risks to personal life (i.e. personal risk perception) are generally rated as less serious compared to risks to society (i.e. societal risk perception) (Bord, O'Connor, & Fisher, 2000; Van der Linden, 2015), this is also expected for risks associated with climate tipping points specifically.

However, previous research that has been discussed in the theoretical framework mainly focused on the general public as opposed to the specific target groups of the current study (participants of UNFCCC negotiations and other professionals that are actively involved in the field of climate change) and this has some implications for what can be expected in the current study. Given that climate negotiation participants as well as climate change professionals are highly involved in climate change issues, it may be assumed that they are more aware of climate change risks and risks associated with climate tipping points specifically and more knowledgeable about climate tipping points compared to the general public. This might also be reflected in high levels of concern of climate tipping points and perceiving associated risks as serious. Higher perceived societal risks compared to personal risks may also be expected in the current study because the impacts of climate tipping points are dispersed throughout the globe and varies across regions. As such, it is not self-evident that study participants perceive the risks of climate tipping points as personally more serious than the general public. The difference in perceived risk to people's own country compared to other countries (Bellamy & Hulme, 2011; Maibach et al., 2008; Spence et al., 2012) might also be expected in study participants of the current study based on Milkoreit's (2017) suggestions regarding differences in engagement with climate action when considering risks to negotiators' own country and culture versus other countries and cultures.

With respect to perceived efficacy, especially participants of the UNFCCC negotiations might perceive a higher level of efficacy regarding governance responses to climate tipping points compared to the general public, because of their active involvement in global climate change politics. Togther with the finding that negotiation participants are generally optimistic about humanity's capability in resolving the problem of climate change (Milkoreit, 2017), it can be expected that participants report relatively high levels of perceived collective efficacy. Study participants might also be more convinced of their own contribution to this (thus relatively high personal efficacy) as they are actively involved in the negotiation process. Climate change professionals might also report higher levels of perceived efficacy compared to the general public, although the difference might be less. For example, climate change professionals within governmental institutions might be involved in formulating national climate policies and professionals within academic institutions might inform climate policy indirectly through providing scientific insights. Although Milkoreit's (2017) findings suggested that participants of global climate negotiations are not necessarily optimistic about the speed and success of the UNFCCC, this perception might have changed since the Paris Agreement. Therefore, it is expected that UNFCCC negotiation participants are more convinced of the capability of the global climate governance community to influence climate tipping points compared to non-participants or the general public. In sum, taking these characteristics into consideration, a relatively high level of risk perception/concern of climate tipping points is expected as well as relatively high levels of perceived efficacy on different levels (personal, UNFCCC community, collective).

Furthermore, governance responses to climate tipping points will involve collective action of multiple stakeholders at various governance levels. Although study participants' personal efficacy might be higher compared to the general public, it is unlikely that they perceive their personal capability of influencing the likelihood of triggering climate tipping points is as high as the perceived collective capability of humanity in general or that of the UNFCCC negotiation community. Therefore, it can be expected that perceived personal efficacy is lower compared to perceived collective efficacy and perceived efficacy of the UNFCCC. Besides that, as appropriate governance responses will require involvement of stakeholders outside the UNFCCC as well, it can be expected that perceived efficacy of the UNFCCC is lower compared to perceived collective efficacy of humanity in general. Furthermore, building on research reporting a positive relationship between climate change risk perception and perceived efficacy (Brody et al., 2008; Heath & Gifford, 2006; Kellstedt et al., 2008; Milfont, 2012; Spence et al., 2011), this can also expected for risks associated with climate tipping points. Bellamy and Hulme (2011) suggested that perceptions of climate tipping points are associated with fear and disbelief in climate change solutions, which indicates a negative relationship between risk perception and perceived efficacy. However, as suggested by Milkoreit (2013) climate change skepticism is less relevant among participants of UNFCCC negotiations and the same might be expected for climate change professionals regarding their active involvement in climate change solutions. Thus, a positive relationship between perceived risks of climate tipping points and perceived efficacy of influencing the likelihood of triggering tipping points is expected in the target groups of the current study.

With regard to differences between participants of the UNFCCC negotiations and non-participants, it can be assumed that climate tipping points and their effects are more salient among negotiation participants because of their more active involvement in climate politics compared to non-participants. Therefore, it may be expected that risks of climate tipping points are perceived as more serious among climate negotiation participants compared to non-participants and that they are more concerned. Following the same reasoning, participants of climate negotiations are expected to perceive the distance of climate tipping points as temporally closer.

Because of the lack of research on perceptions of climate tipping points, related factors of perceived risk and efficacy will be further explored using an inductive approach by means of qualitative analysis.

3.2 Hypotheses on the effects of the game on perceived risk and efficacy

The game ("The Tipping Negotiations") that was developed in the Gaming Climate Futures project is a computerized role-playing negotiation simulation exercise focused on climate tipping points and global temperature goals. The main objective of the Tipping Point Negotiations was to inform participants of the UNFCCC negotiations about the nature and importance of climate tipping points and engaging them in imagining the types of futures their collective decision-making process could create. After a brief introduction on climate tipping points, in Part 1 of the Tipping Point Negotiations, participants play the roles of country representatives and negotiate on climate change mitigation and adaptation investments in five negotiation rounds. The main goal of this part of the game (win condition) was to collectively prevent tipping points from passing. A climate model that runs during the negotiation rounds shows real-time dynamics in the climate system including global temperature increase and triggering of climate tipping points, based on the decisions of participants. Part 2 of the Tipping Points Negotiations consists of a story-telling climate fiction exercise in which participants collaboratively create storylines of imaginary future characters that live in places that are affected by the impacts of climate tipping points that are passed. The game is described in further detail in the method section. Some hypotheses were formulated on the way each game element might influence perceived risk and efficacy, which is summarized in Figure 3.

3.2.2.1. Introduction

An introduction on climate tipping points was expected to improve participant's knowledge about climate tipping points, particularly on their dynamics, complexity, uncertainty, impacts and the relationship between global temperature goals.

3.2.2.2 Part 1: UNFCCC negotiations

It was expected that knowledge on climate tipping points was further addressed by actively exploring the dynamics and the relationship with global temperature by taking collective and individual decisions and observing the consequences of those decisions. Also, participants were expected to learn more about decision-making challenges (e.g. differences in vulnerability and resources and trade-offs between short-term and long-term decisions) and about the type of impacts of climate tipping points on various regions across the globe. Risk and efficacy perceptions were expected to be influenced through those knowledge gains. By means of visuals and narratives about those impacts, it was expected that an 'imagined' experience of impacts was created, which might influence risk perceptions both directly and through eliciting emotional responses (e.g. fear, worry or sadness). The negotiations involve interaction with other players, which was expected to influence participant's beliefs about negotiation mandates or perspectives of other actors. This could in turn create or reduce empathy for perspectives and decision-making strategies of other players which might influence reciprocal trust in each others contributions to the collective goals, which might in turn affect efficacy perceptions. On the other hand, interactions may also reduce their empathy and trust, when experiencing reluctance of other players to contribute. The interaction and the decision-making challenges might also evoke emotions such as frustration (e.g. by their limited resources or unsuccessful negotiation process), excitement (e.g. if collective goals are reached) or disappointment (e.g. when a new tipping points is passed), which might also influence efficacy perceptions. In addition, experience of success of collective action during the negotiations, such as successfully avoiding further passing of climate tipping points by limiting global warming to a certain extent, might enhance perceived collective efficacy of avoiding climate tipping points. On the other hand, a failure of collective action to limit global warming, resulting in further passing of climate tipping points, might reduce perceived collective efficacy of influencing their likelihood. In addition, perceived personal efficacy might be influenced either positively or negatively by showing individual contributions to reaching collective goals and their influence on decisions of other participants.

3.2.2.3. Climate fiction story-telling exercise

During the transition and story-telling exercise, participants engage in 'future thinking' by imagining the possible futures that might result from their collective decision-making during the negotiation. It was expected that this way, the timeframes that participants have in mind when thinking about the future was extended to much more long-term. By imagining futures in terms of long-term impacts, participants were expected to imaginatively experience possible future risks that climate tipping points pose to different places around the world, which was expected to provide insights in the possible future risks of climate tipping points on a much more local, emotional and personal level rather than a global, abstract and objective level. This might change how participants perceive the risks of climate tipping points, particularly perceived temporal distance and personal risk. Imagining future impacts of climate tipping points on a personal level might induce various positive or negative emotional/affective responses, such as feelings of hopelessness or despair (e.g. because of the miserable prospects of the imaginative characters), sadness (e.g. because of the tragic events that might happen) or excitement (e.g. about potential positive impacts of climate tipping points). These emotions and affective responses might in turn influence perceived risk and efficacy.

3.2.2.4 Debriefing

The debriefing session is included for participants to reflect on their experiences. It can be expected that this reflection makes participants more aware of changes in knowledge in perceptions and thereby enhances the overall effectiveness of the role-playing simulation game.

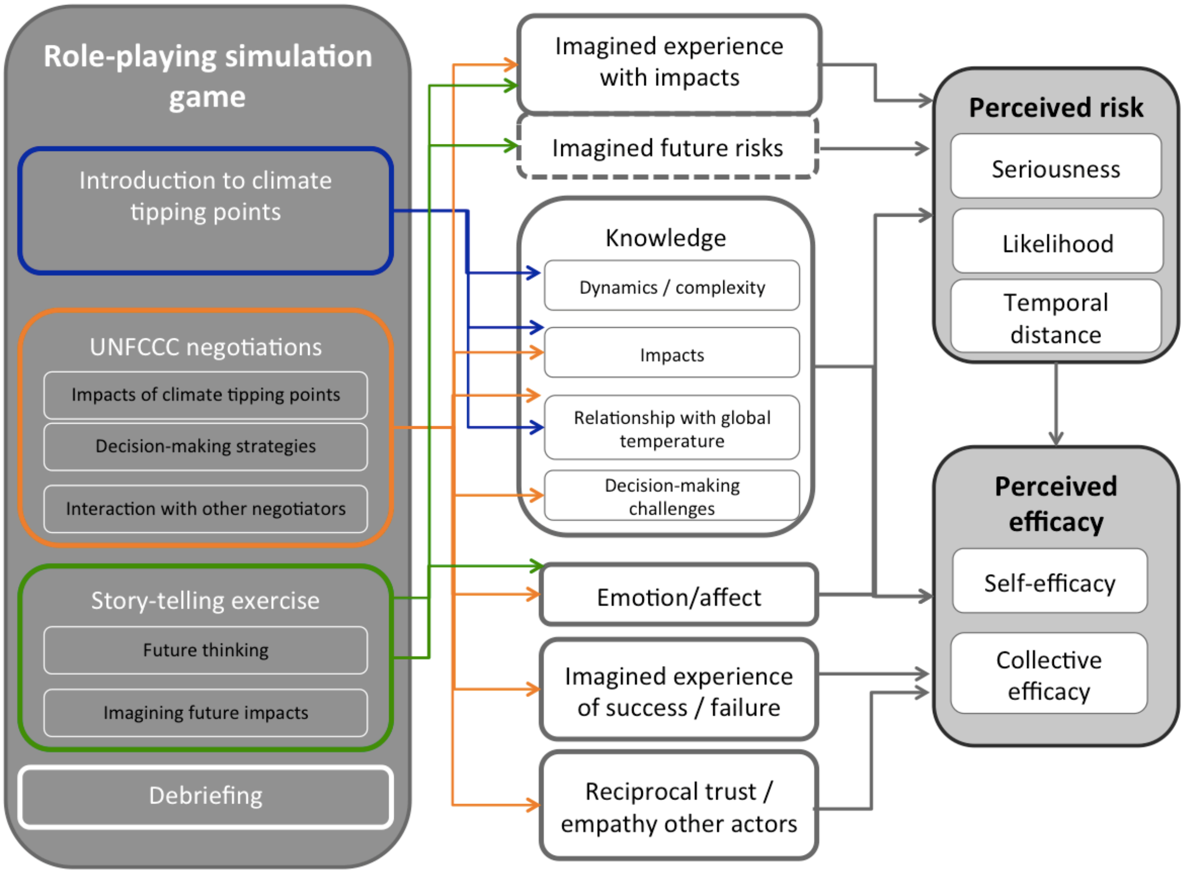


Figure 3. Framework of proposed effects of each game element on factors underlying risk perception and perceived efficacy.

4. Methods

4.1 Materials and procedure

In order to create a more elaborate understanding of the perception of risks associated with climate tipping points and perceived efficacy to influence them, the role of serious gaming to influence these perceptions, a mixed-method approach was taken. A combination of different data collection methods was used, known as triangulation of data (Williamson, 2005). Because the perceptions of climate tipping points are largely unknown, a survey among professionals that are actively working on climate change provided further exploration of the perceptions of risks and efficacy and underlying factors and relationships. Secondly, analysis of changes in perceptions of risks and efficacy regarding climate tipping points by means of pre- and post-surveys (containing the same questions of the online survey) provided insights in the effectiveness of the role-playing simulation game. Furthermore, a literature review resulted in a better understanding of the theoretical implications of findings.

4.1.1 Literature review

As indicated in the introduction, sub questions 1, 2 and 4 of this research were addressed by reviewing literature. With regard to risk perception, the 'psychometric paradigm' was mainly focused on which has been particularly addressed in cognitive science literature. Perceived efficacy is a psychological construct, building on well-known psychological theories including Social Cognitive Theory (Bandura, 1998; 2000) and the Theory of Planned Behavior (Ajzen, 1988; 1991). The literature review focused on research on risk and efficacy perceptions in relation to climate change risks and responses to climate change, which has been addressed in various fields of literature, including risk analysis, psychology and political science. Furthermore, literature in the fields of political science, behavioral economics and environmental science was reviewed that focused on the role of cognition in global climate governance and decision-making in response to climate tipping points. In addition, in answering sub question 4, literature in the fields of simulation gaming, game-based learning and educational psychology was particularly focused on. With regard to serious gaming in relation to climate change governance, a broader range of literature was approached, including science communication, environmental science and policy literature.

4.1.2 Role-playing simulation game

The role-playing simulation exercise was performed in three workshop sessions facilitated by members of the Gaming Climate Futures project, that were held in Bonn during UNFCCC SB48 in May 2018. The role-playing simulation exercise ("The Tipping Point Negotiations") was performed three times in three-hour workshop sessions that were held in a conference room in Bonn during UNFCCC SB48 in May 2018. The role-playing simulation exercise consisted of two parts. Part 1 consisted of a role-playing exercise (formal negotiation simulation), played in personal interaction with other players (max 30) and Part 2 consisted of a climate fiction storytelling exercise that built on the results of Part 1. Each workshop element is described in further detail below. Effects on knowledge, beliefs, future thinking and risk and efficacy perceptions of game participants were analyzed using a quasi-experimental approach by comparing responses to a pre- and post-survey as well as by observations (see section 4.1.2.3). The current research focuses merely on the survey items that addressed risk and efficacy perceptions. The Tipping Points Negotiation game was tested multiple times in order to improve the quality of the game and research design. Part 1 of the game was subject to three formal test sessions with undergraduate students at Purdue University in April 2018 by project members from Purdue University. Part 2 of the game was tested with undergraduate students at Utrecht University by Joost Vervoort and me. (See Appendix II for a more elaborate description of game development).

4.1.2.1. The Tipping Point Negotiations Game

Introduction

In order to provide a basic understanding of climate tipping points, a short presentation about climate tipping points is provided, including a definition, introduction videos that were created for this project in which tipping points are explained by Tim Lenton (who can be considered a scientific expert on climate tipping points); elaborating on non-linearity, dynamics and potential impacts and the relationship between the likelihood of passing climate tipping points and global temperature increase. In a presentation, the relationship between global temperature goals and climate tipping points (e.g. using figures developed by Schellnhuber et al., 2016) are explained by the workshop facilitator. The following tipping elements are included in the game; Coral Reef Dieback, West-Antarctic Ice Sheet collapse, Arctic Summer Sea Ice loss and shifts in the Indian Summer Monsoon (see Appendix II for elaboration on the selection of tipping elements). This introduction is followed by a brief Q&A.

Part 1: UNFCCC Negotiations

The game rules are explained by the workshop facilitator; The negotiation resembles real-life UNFCCC negotiations in which each player plays the role of a representative of a country (the game was designed for a maximum of 30 countries) within an alliance, with the task to limit global temperature and avoiding climate tipping points from passing. All participants receive a country profile containing information that might influence the decision-making during the negotiation, including geography, economy, current emissions, energy profile, climate change risks and vulnerability and negotiation stance and history and negotiation mandate (based on actual NDCs) as well as game instructions. The negotiation consists of five rounds, each round representing five years, starting with the current year (2018) and ending in the year 2043. Before the first round of negotiations, current (i.e. 2018) global temperature, sea level rise and the (whether or not) passing of climate tipping points is shown on the moderator screen. Each round, participants negotiate with other participants on how to allocate their national budget on either domestic climate change mitigation, domestic climate change adaptation, the International Climate Fund (ICF; collective fund for climate change adaptation that is distributed among vulnerable countries when a particular contribution threshold is reached) or a Negative Emissions Technology Fund (NET; collective fund for development of negative emissions technologies that start reducing global emissions when a particular contribution threshold is reached). At the end of each round, participants enter their submissions of budget allocations by moving sliders on an electronic device. This is used as input for a climate simulation model, which provides effects of all budget allocations on global temperature, sea-level rise and whether one or more tipping points have been passed. These effects are shown on the moderator screen, as well as contributions to the ICF and NET after each round of negotiations. The moderator provides a brief update of the global and regional impacts of the tipping points that have been passed so far in the game (i.e. the Coral Reef Dieback tipping point is passed already at the beginning of the game). Countries that are particularly affected during the negotiations receive event cards describing on one side a catastrophic country-specific event with economic consequences, with an image of this event on the other side. This negotiation process is repeated until the year 2043 is reached.

Transition

A transition from Part 1 and Part 2 is included which fast-forwards from the year 2043 to the year 2118 (100 years from now, at the time of writing). The major global trends (based on IPCC (2014) scenarios and Shared Socio-Economic Pathways (e.g. O'Neill et al., 2014); in this time period are shortly described and participants shortly discuss how these change might affect the countries they were playing during the negotiations, which encourages their 'future thinking'.

Part 2: Climate fiction story-telling exercise

Participants are divided in groups and receive a story preamble about an imaginary character that is living in the year 2118 in a specific place that is affected by the impacts of climate tipping points. Each story preamble is linked to one of the tipping elements included in the Tipping Point Negotiations (Coral Reef Dieback, WAIS, ASSI, Boreal Forest Shift/Dieback or Indian Summer Monsoon). Each group determines a storyteller and a note taker. Their group task is to finish this story preamble by thinking about possible endings, character developments, what their daily life would be like, how the changes in this location affects their decisions, etc. Participants brainstorm about these aspects in their groups. At the end of Part 2, the storyteller of each group shares their created storyline in plenary.

Debriefing

Participants are asked to reflect and share their learning experiences, feelings, changes in perceptions and decision-making strategies.

4.1.2.2. Recruitment and participants

Identification of potential workshop participants (diplomats and NGO representatives) was based on participant lists of COP 23 provided by the UNFCCC. Online search was performed to identify contact information, in an effort to ensure diversity and full representation of all negotiation alliances and major interests. With regard to NGO representatives, at least 5 organizations in each NGO group were invited (Environmental NGO, Development NGO, Climate Justice NGO, Indigenous Groups, Industry, Green Industry, Youth, Cities and Municipalities and Others). A total of 38 individuals participated in the workshops (57% male, 43% female, $M_{age} = 36.9$, age range: 21-61) of which 32 representatives of non-state actors and six diplomats.

4.1.2.3. Procedure

The procedure of the game session was as follows:

- Step 1: Participants were invited to fill in an online pre-workshop survey 2 weeks in advance of the workshop session.
- Step 2: Participants entered the room and signed written consent forms.
- Step 3: Participants who did not fill in the online survey filled in a paper-based pre-workshop survey (containing the same questions).
- Step 4: Participants received information about climate tipping points by means of a power point presentation and introduction videos.
- Step 5: Game instructions were provided by the facilitator.
- Step 6: Participants engaged in the role-playing simulation exercise (the Tipping Points Negotiations). Part 1: in each round participants each represented a country and took decisions on how to allocate their budget among four decision options (domestic climate mitigation, domestic climate adaptation, investing in International Climate Fund, investing in Negative Emissions Technology Fund). Before making these decisions, participants had the opportunity to negotiate with other participants to influence collective outcomes. After each round, changes in global temperature and effects on triggering tipping points were shown on a screen based on the decisions in that negotiation round. A total of five negotiation rounds were played (see section 3.2.1 for more elaborate description).

- Step 7: Facilitators provided a transition narrative describing changes between 2043 and 2218 and invited participants to reflect on changes in participants' home country (see section 3.2.1)
- Step 8: Participants were divided in groups of 3-5 and received fictional story pre-ambles of characters living in the distant future, experiencing the effect of climate tipping points. Participants collaboratively created story endings by means of imagining the impacts of climate tipping points on the characters' daily lives. One member of each group shared their story in the workshop plenary (see section 3.2.1).
- Step 9: Debriefing session in which participants reflected on learning experiences during the game play session.
- Step 10: Participants were invited to fill in an online post-workshop survey after the workshop session and received two reminders to complete this within a month following the workshop.

4.1.2.4. Data collection

The data collection of the workshop sessions was a collective process coordinated by the project leader, in which I participated (see Appendix III). Five members of the Gaming Climate Futures project team developed a survey instrument, coordinated by the project leader. The survey covered multiple kinds of cognitive phenomena, including knowledge, beliefs, risk perceptions, efficacy perceptions and future thinking, including questions that were answered using a 5-point Likert scale and open questions. This allowed for quantitative as well as qualitative analysis. I was responsible for developing survey questions on risk perception (concern, perceived seriousness, likelihood and perceived temporal distance) and efficacy perceptions (personal efficacy, collective efficacy, efficacy of the UNFCCC, country-level efficacy), (see 4.2 for operationalization of variables and Appendix IV for survey items). The same survey instrument was used for the pre-and post-workshop surveys. Response rates of pre- and post-workshop surveys were 84% (N=32) and 37% (N=14) respectively. With regard to perceived efficacy, an open question was included in which participants were asked to provide comments on their responses on the Likert scale questions. No open question specifically addressed risk perception, but participants were asked to indicate whether and why climate tipping points are important or not important for policymakers, which was assumed to contain some qualitative data on risk perception.

Based on the experience with time requirements of the pre-workshop surveys, the survey instrument was shortened after the workshop sessions and before inviting participants to complete the post-workshop surveys. This has resulted in elimination of several items concerning risk and efficacy perceptions in the post-workshop surveys. However, the number and variety of items remained sufficient to perform analysis of risk perception (16 items) and perceived efficacy (7 items). Due to missing data, pairwise comparison of survey responses on risk and efficacy perceptions of pre- and post-workshop responses was performed for only a share of workshop participants (N=10).

Additional data during workshop sessions was obtained by means of observations of four members of the Gaming Climate Futures project team, including me. Observational notes were taken during the complete workshop session (including debrief session) and included participant's learning experience, emotional experience, comments, formal statements after negotiation rounds, interactions during negotiation and results of the storytelling exercise. This research focuses particularly on observational notes concerning risk perception and perceived efficacy.

4.1.2.5. Game development

The development of the Tipping Point Negotiations game was a collaborative process between members of the Gaming Climate Futures project (see Appendix II).

4.1.3 Online survey

Using the same (shortened) survey instrument that was used for post-session data collection, an online survey was disseminated by me, among professionals that are actively working in the field of climate change, in order to obtain insights into their knowledge, beliefs and perceptions regarding climate tipping points and global temperature goals. The survey was distributed among the following networks and organizations of climate change professionals (see 4.1.3.1).

4.1.3.1. Participants

It was assumed in this study that in order to analyze risk and efficacy perceptions on climate tipping points, at least a modest understanding of climate tipping points is required. Therefore, the survey was disseminated through various networks of professionals that are actively working in the field of climate change within academic institutions, NGOs, governments, media and the private sector. The survey was disseminated throughout the following networks: The CGIAR Research Program on Climate Change, Agriculture and Food Security (NGOs, researchers, governments), Food&Business Knowledge Platform (Dutch government, NGOs, private sector, researchers), Research School for Socio-Economic and Natural Sciences of the Environment), Earth System Governance (researchers), network of BNP Paribas project RE-IMAGINE Anticipatory Climate Futures (PhD researchers), Environmental Governance Research Group (researchers at Utrecht University), Platform for African European Partnership on Agricultural Research for Development (NGOs, private sector), Network of Women in Agribusiness and Development (NGO), Royal Netherlands Meteorological Institute (climate change department, government), Climate Central (researchers, journalists), Greenpeace International (Climate and Energy Team, NGO), PBL Netherlands Environmental Assessment Agency (climate change department, government), Dutch National Institute for Public Health and the Environment (climate change department, government). This target group was is assumed to have sufficient knowledge of climate change and have at least a modest understanding of climate tipping points. A total of 46 climate change professionals (27 men, 19 women, M_{age} = 40.8, age range: 22-62) participated in the online survey, with 15 different nationalities (39.1% Dutch, 21.7% American, 10.9% German) from varying organizations (43.5% academic institutions, 23.9% non-governmental organizations, 21.7% government institutions, 6.5% private sector) and varying areas of expertise within climate change, including climate change adaptation and mitigation policy, energy, ecosystem impacts, hydrological impacts, agriculture and forestry related to climate change, (paleo)climate modeling and so on. The survey was available to respondents for 5 weeks in June and July 2018.

4.1.3.2. Procedure

- Step 1: Subjects received a survey invitation via email or social media with Qualtrics survey link.
- Step 2: Subjects visited the online survey page (Qualtrics) in which they first provided informed consent before proceeding to the survey questions. Completing the survey took about 15 minutes.

4.1.3.3. Data collection

The same (shortened) version of the survey instrument used for the pre- and post-workshop surveys was used to create the online survey in Qualtrics (see Appendix IV for survey instrument). Additional questions in the online survey that were not included in the pre-and post-workshop survey instrument were a question regarding participation of UNFCCC meetings (whether the professionals participated in any UNFCCC meeting in the past and if so, how many and what role they fulfilled) and fields of expertise within climate change.

4.2 Operationalization of variables

4.2.1 Risk perception

Risk perception was measured by means of multiple items, based on previous research (Brody et al., 2008; Kahan et al., 2012; Kellstedt et al., 2008; Stevenson et al., 2015; Sundblad et al., 2007; Van der Linden, 2015). This included items of perceived seriousness of the risk of passing tipping points and concern, that were rated on 5-point Likert-scales (1 = *not serious/not concerned, 5 = extremely* *serious/extremely concerned)*. Following Van der Linden (2015), a distinction was made between personal risk perception (risks of climate tipping points affecting personal life) and societal risk perception (risks of climate tipping points to society). In addition, within personal and societal risk perception, a distinction was made between perceived risks for (1) food and water security, (2) security and (3) prosperity (see Appendix IV for complete survey instrument). Given the acceptable level of Cronbach's alpha of internal consistency of 0.7 (Cortina, 1993), a reliable Risk Perception Index was obtained based on all ten risk perception items (α = 0.85). In addition, reliable Personal Risk Index (α = 0.90) and a Societal Risk Index (α = 0.77) were obtained based on three items each.

Some elements that can be considered important in how risks of climate tipping points are perceived are (1) the perceived likelihood of passing tipping points and (2) the perceived temporal distance of the impacts of climate tipping points. In the current study, these elements are approached separately from the other risk perception items, although considered highly relevant to risk perception. Participants were asked to rate the their perceived likelihood of passing two tipping elements, i.e. Coral Reef Dieback and Arctic Summer Sea Ice, on a scale from <1% (exceptionally unlikely) to >99% (virtually certain). In addition, participants were asked to indicate the perceived temporal distance of impacts of four tipping elements (i.e. Coral Reef Dieback, West-Antarctic Ice Sheet, Boreal Forest Shift/Dieback and Arctic Summer Sea Ice) as either short-term (immediately / after a few years), medium term (after a few decades) or long-term (after a century).

4.2.2 Perceived efficacy

In the current research, perceived efficacy was measured with multiple questions including questions on personal and collective efficacy based on Brody et al. (2008), Kellstedt et al. (2008), Milfont (2012) and Hornsey et al. (2015). Participants indicated their level of agreement on five items using a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*). In the context of the current study, personal efficacy relates to the perceived ability of climate negotiation participants or climate change professionals to influence the likelihood of avoiding or triggering climate tipping points. Collective efficacy entails perceived capability by countries to collectively influence avoiding or triggering tipping points. Furthermore, participants were asked to rate the perceived efficacy of the UNFCCC negotiation community. In addition, three items regarding the relative perceived influence of different countries within the UNFCCC were included; the belief that efficacy of the UNFCCC is dependent on the willingness of a small number of important actors, the belief that the participant's own country is part of this group of actors and the belief that this country is able to influence decision-making of this group. See Appendix IV for complete survey instrument.

4.3 Data analysis

4.3.1 Quantitative data analysis

Quantitative data consisted of all responses on 5-point Likert scale questions in the online survey among climate professionals as well as the pre-workshop surveys (partly paper-based and partly online) and post-workshop surveys (online) of workshop participants. The data from pre-workshop surveys (N=32) was merged with data from the online survey among climate change professionals (N=46) in order to obtain a larger dataset that allowed for more variety of statistical analyses and higher statistical power. However, there are some potential biases that should be taken into account when merging these datasets, in terms of population sample as well as survey mode (online vs. paper-based) that will be shortly discussed before going into detail about the statistical analyses.

Some advantages of online surveys are that a larger population size can be reached (enhancing external validity), surveys can be distributed at lower costs and there are no time limitations (Riva, Teruzzi, & Anolli, 2003). However, disadvantages are that the study environment is difficult to control and participants are not monitored (Riva et al., 2003). In the current study, this means there is no control on the environment in which online survey participants filled in the survey, whether they accessed the Internet for information, filled in surveys themselves or together with others, etc. These factors might have influenced survey responses regarding knowledge and perceptions of climate tipping points. Moreover, another potential bias is that participants of online surveys are self-selected and are thus a random selection of the population can not be ensured (Riva et al., 2003). Although control of the environment and monitoring participants is better with the paper-based pre-workshop surveys, this survey mode might be subject to biases as well. In particular the interviewer effect: due to the presence of an interviewer, survey responses are more likely to be socially desirable (Duffy, Smith, Terhanian, & Bremer, 2005). The presence of facilitators of the workshop during completion of the paper-based surveys might have influenced responses, especially regarding perceptions and beliefs about importance of climate tipping points. Previous research comparing online with paper-based versions of the same surveys revealed some differences such as that online surveys have lower response rates (Nulty, 2008), less missing data and faster survey completion (Lonsdale, Hodge, & Rose, 2006). Whereas others found no or only small differences between online and paper-based surveys in mean scores (Buchanan & Smith, 1999) and reliability of psychological constructs (Riva et al., 2003). Taking into account potential biases in survey responses, statistical analyses were performed comparing online surveys (N=56) versus paper-based surveys (N=21) and survey responses of workshop participants (N= 32) versus responses of climate change professionals (N=46) as well as analysis of the merged dataset (N = 78).

Furthermore, Cronbach's alpha was calculated to obtain reliability of the risk perception scales. Statistical data analyses of Likert-scale questions of the pre- and post-surveys of the game sessions and the online survey were performed using SPSS. Although Likert-scales are formally ordinal scales that allow only non-parametric statistical tests, the current study assumes equally spaced categories, allowing for parametric statistical tests (for a discussion, see for example Derrick & White (2017) and Norman (2010)). For perceived temporal distance, the time scales do not represent equally spaced categories (category 1 (immediately/after a few years), category 2 (after a few decades) and category 3 (after a century)) and therefore non-parametric statistical tests were performed.

Pairwise comparisons (paired sample t-test) were performed to analyze differences in mean scores of responses between pre-workshop and post-workshop surveys (N=10). Paired sample t-tests were also performed to analyze differences between different risk perception measures within subjects; differences between societal risk perception and personal risk perception and differences between (1) food and water security, (2) security and (3) prosperity and between perceived likelihood of different tipping points. A Wilcoxon signed-rank test was performed to reveal differences in perceived temporal difference between the different tipping points. Within-subject differences between personal and collective efficacy were also analyzed by performing paired sample t-tests.

Between-subject comparisons of mean scores on risk perception and perceived efficacy items were performed using independent t-tests; online surveys vs. paper-based surveys, workshop participants vs. climate change professionals and participants of the UNFCCC negotiations vs. non-participants. With regard to the latter, all workshop participants were considered UNFCCC negotiation participants since they attended (at least) UNFCCC SB48. Also climate change professionals who indicated to have attended (one or more) UNFCCC meeting(s) in the past were considered UNFCCC participants. Climate change professionals who never attended any UNFCCC meeting were considered non-participants. With regard to perceived temporal distance of impacts of the different climate tipping points, Mann-Withney U tests were performed to analyze between-subject differences. Additionally, a one-way analysis of variance (ANOVA) was performed to analyze differences in perceived risk and efficacy between different types of organizations that climate change professionals are most active in and differences between roles at the UNFCCC negotiations. Pearson correlation analyses were performed to analyze correlations between risk perception and perceived efficacy.

4.3.2 Qualitative data analysis

Qualitative content analysis of open-ended survey questions and observational data was performed using NVivo in order to analyze underlying reasoning of perceptions of risks and efficacy regarding climate tipping points and the changes in perceptions as a result of engaging in the role-playing simulation game. Because participants were engaged in a role-playing game in which they take on a different role than their role in reality, observations that might reveal information about their perceptions are considered invalid. For example, a participant might express extreme concern when playing a country that is highly affected by climate tipping points (such as one of the small island states), but this participant might in reality be not as much concerned. Because it is not possible to distinguish between expressions of actual perceptions and expressions of the role participants are playing in the Tipping Points Negotiations game, only responses to open questions were analyzed to analyze underlying reasoning of perceptions of risks and efficacy. During the debriefing session however, participants are no longer play the role of country representatives and are assumed to express their actual perception. Therefore, participants' statements during the debriefing sessions were analyzed to reveal insights in changes in perceptions of risks and efficacy.

Responses on several open questions of the survey among climate change professionals (N=46) and pre-workshop surveys (N=32) were combined and collected. No open question specifically addressed perceived risk, but participants were asked to comment on whether and why climate tipping points are important or not important for policymakers, which might contain about perceived risk because this is assumed to be partially similar to asking participants whether and why policymakers are concerned or not concerned about climate tipping points. First a distinction was made between participants that indicated that climate tipping points are not (considered) important by policymakers and participants that indicated tipping points are (considered) important by policymakers (see Appendix VI A for codebook). Subsequently, as responses to this question may reveal information about risk perceptions including perceived likelihood, perceived (temporal) distance and perceived seriousness of the risks, a codebook was developed by coding responses to this question into categories of those three elements of risk perceptions (see Appendix VI B for codebook). Additional perceptions that did not match either of these categories were coded into additional categories, based on similarities between responses. Thereafter, sub categories were identified based on similarities between responses in order to provide a deeper understanding of underlying reasoning behind risk perceptions. Furthermore, the types of impacts of climate tipping points were identified in order to analyze the types of risks that are considered by participants when answering this question. All in all, this resulted in a framework of different types of reasoning behind perceived (lack of) importance of (the risks of) climate tipping points for policymakers.

With respect to perceived efficacy, participants were asked to further comment on their responses on Likert-scale perceived efficacy questions. Responses to this open question were analyzed in order to identify underlying reasoning behind perceived (lack of) collective efficacy, personal efficacy, country-specific efficacy and efficacy of the UNFCCC community. First, statements were categorized into statements about lack of perceived efficacy and statements about high levels of perceived efficacy (and a residual category where this is not clear). Subsequently, the perceived efficacy statements were divided into the different types of perceived efficacy (collective, personal, country-specific, personal) and additional categories were identified if necessary (See Appendix VI E for codebook). Thereafter, based on similarities between statements, a codebook was developed of the different types of underlying reasons behind each perceived efficacy category, based on similarities in responses (see Appendix VI G for codebook)

In order to reveal insights in the changes in perceptions during engagement in the role-playing simulation game, observational notes of four observes (who are members of the Gaming Climate Futures project team) of the debriefing session were analyzed, focusing on perceptions of risks and efficacy. A codebook was developed based on previous research to reveal criteria to reveal statements containing perceptions of risks and efficacy (see Appendix VI H).

5. Results

5.1 Perceived risk and efficacy

5.1.1 Quantitative results

5.1.1.1 Risk perception

Rated on a 5-point Likert scale, combined data of climate change professionals and workshop participants (N=78) indicated above medium levels on the Risk Perception Index as well as on Societal Risk Perception and below medium levels on Personal Risk Perception (see Table 2). With respect to individual risk perception items, participants rated perceived seriousness of the risks of climate tipping points in general, perceived seriousness of risks to their own country, to society and to other countries and concern on above medium levels (see Appendix V A).

	Statistic		
Risk perception item	*M*	*SD*	*N*
Risk Perception Index	3.66	.69	69
Societal Risk Perception	4.15	.79	72
Personal Risk Perception	2.62	1.13	71

Table 2. Summary of descriptive statistics of risk perception indices (Mean, Standard Deviation and sample size).

Of all survey responses (N=78), no participants indicated to have no concern of climate tipping points and no participant perceived the risks of climate tipping points as not serious. Regarding concern about climate tipping points, 8% indicated to be somewhat concerned, 16% concerned, 25% rather concerned and 52% extremely concerned (Figure 4A). In general, tipping points were perceived as at least serious by 96% of participants, of which 41% extremely serious (Figure 4B).

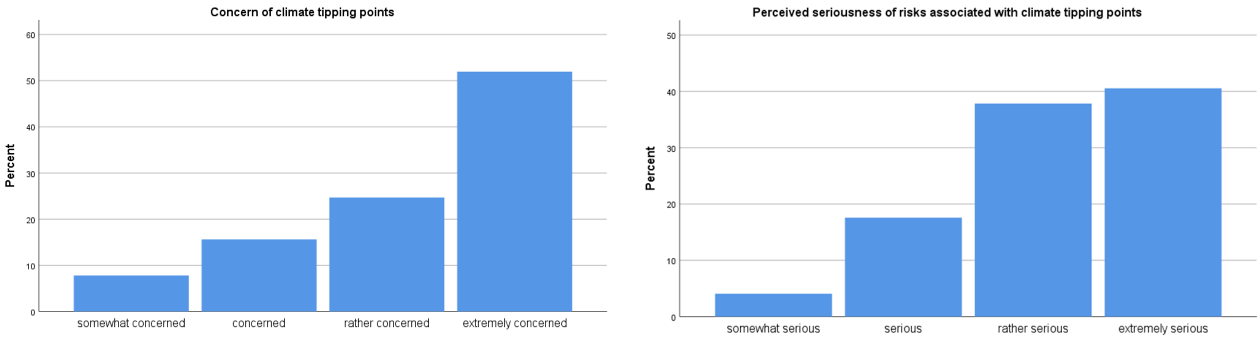


Figure 4. A. Distribution of responses (in percentages) to the question "How concerned are you about climate tipping points?". *B.* Distribution of responses (in percentages) to the question "In your judgment, how serious of a risk do you think climate tipping points are in general?"

As shown in Figure 5, the risks of climate tipping points were perceived as extremely serious for participant's own country by 33% and by 64% when considering risks for other countries.

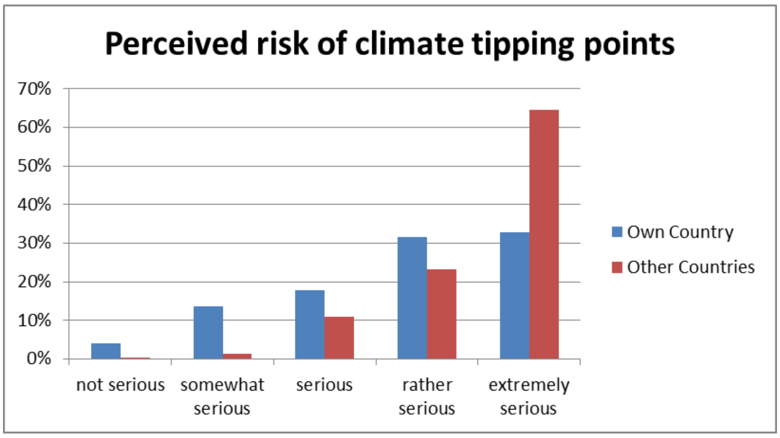


Figure 5. Distribution of responses (in percentages) to the questions 'In your judgment, how serious of a risk do you think climate tipping points are in general for the country you live in / other countries?'

Mean scores of perceived likelihood of the Coral Reef Dieback and Arctic Summer Sea Ice (ASSI) tipping points are shown in Table 3 (different scales were used for the survey among climate change professionals and surveys among workshop participants).

			Statistic		
Sample population	*Variable*	*Scale*	*M*	*SD*	*N*
Climate change professionals	LikelihoodCoralReef	1-99	56.42	29.18	38
	LikelihoodASSI	1-99	58.56	27.13	39
Workshop participants	LikelihoodCoralReef	1-6	4.21	1.20	28
	LikelihoodASSI	1-6	3.52	1.25	27

Table 3. Summary of desctiptive statistics of perceived likelihood of passing the Coral Reef Dieback ('LikelihoodCoralReef') and Arctic Summer Sea Ice tipping elements ('LikelihoodASSI'): M=Mean Score, SD=Standard Deviation, N=sample size.

Among participants, as illustrated in Figure 6, a majority expected impacts of the Coral Reef Dieback (if passed) as immediate or after a few years (short-term perceived temporal distance). For the West-Antarctic Ice Sheet (WAIS), this was approximately half of the participants. For the Boreal Forest Shift/Dieback and Arctic Summer Sea Ice (ASSI) tipping points, relatively more participants expected impacts on the medium-term (after a few decades). Only a minority of participants reported long-term (after a century) perceived temporal distance of climate tipping points (4-13%).

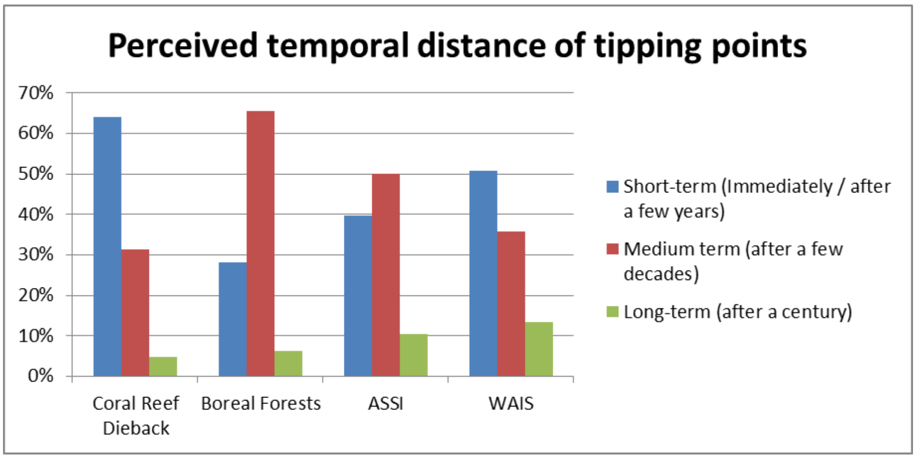


Figure 6. Distribution of responses (percentages) to perceived temporal distance of four tipping elements: Coral Reef Dieback, Boreal Forest Shift/Dieback, Arctic Summer Sea Ice (ASSI) and West-Antarctic Ice Sheet (WAIS).

Comparing survey responses on risk perception items between the survey among climate change professionals and the pre-workshop survey among workshop participants, significant differences in mean scores were found on all risk perception indices (see Table 4).

Outcome	Group						95% CI for Mean Difference		
	Workshop participants			Climate change professionals					
	M	*SD*	*n*	*M*	*SD*	*n*		*t*	*df*
RiskPerceptionIndex	3.962	.569	24	3.496	.696	45	-.797, -.137	-2.821*	67
SocietalRiskPerception	4.444	.641	27	3.970	.822	45	-.779, -.155	-2.563*	70
PersonalRiskPerception	3.128	1.265	26	2.312	.943	45	-1.386, -.234	-2.839*	69

*p<0.05

Table 4. Summary of statistics of independent sample t-test comparing mean scores of workshop participants with climate change professionals on three risk perception indices: Risk Perception Index, Societal Risk Perception and Personal Risk Perception. M=Mean Score, SD=Standard Deviation, n=sample size, 95% CI= 95% confidence interval at α = 0.05 t = critical t value, df = degrees of freedom.

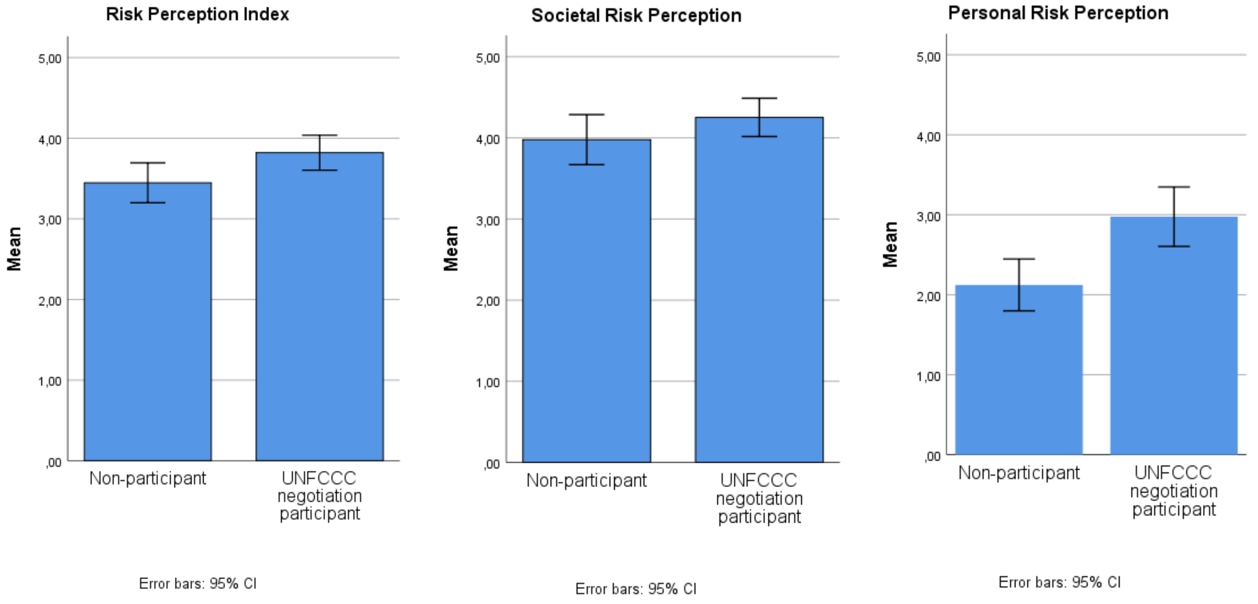
Regarding the type of survey format (online vs. paper-based), mean scores of Risk Perception Index and Societal Risk Perception were significantly lower among online survey participants compared to paper-based survey participants (see Table 5). No significant differences in mean scores of Personal Risk Perception were found between online versus paper-based survey participants. Despite the large difference in group sizes, Levene's test revealed that equality of variances may be assumed, hence comparison of the groups by means of the independent t-test is considered valid.

Outcome	Group						95% CI for Mean Difference		
	Online survey			Paper-based survey					
	M	*SD*	*n*	*M*	*SD*	*n*		*t*	*df*
RiskPerceptionIndex	3.55	.699	53	4.05	.522	15	-.885, -.107	-2.546*	66
SocietalRiskPerception	4.01	.822	54	4.59	.507	17	-.998, -.154	-2.724*	69
PersonalRiskPerception	2.51	1.27	53	2.98	1.266	17	-.1110, -1.175	-1.497	68

*p<0.05

Table 5. Summary of statistics of independent sample t-test comparing mean scores of online survey responses with climate mean scores of paper-based survey responses on three risk perception indices: Risk Perception Index, Societal Risk Perception and Personal Risk Perception. M=Mean Score, SD=Standard Deviation, n=sample size, 95% CI= 95% confidence interval at α = 0.05 t = critical t value, df = degrees of freedom.

Furthermore, differences in mean scores on risk perception indices were found between UNFCCC negotiation participants (i.e. climate change professionals who attended UNFCCC meetings in the past and all workshop participants at SB48) and non-participants (i.e. climate change professionals that never attended any UNFCCC meeting in the past), as demonstrated in Figure 7A-C.



A. *B.* *C.*

Figure 7. A: Mean scores on Risk Perception index comparing UNFCCC negotiation participants with non-participants, with 95% confidence intervals. B: Mean scores on Societal Risk Perception comparing UNFCCC negotiation participants with non-participants, with 95% confidence intervals. C: Mean scores on Personal Risk Perception comparing UNFCCC negotiation participants with non-participants, with 95% confidence intervals.

As shown in Table 6, significant higher scores on Risk Perception Index (see also Figure 7A) and Personal Risk Perception (see also Figure 7C) were found for UNFCCC negotiation participants, compared to non-participants. No significant differences were found for societal risk perception (see Figure 7B)

Outcome	Group						95% CI for Mean Difference		
	UNFCCC negotiation participants			Non-participants					
	M	*SD*	*n*	*M*	*SD*	*n*		*t*	*df*
RiskPerceptionIndex	3.821	.669	39	3.447	.663	30	-.697, -.051	-2.309*	67
SocietalRiskPerception	4.270	.748	42	3.978	.826	30	-.664, -.0880	-1.564	70
PersonalRiskPerception	2.976	1.177	41	2.122	.869	30	-1.361, -.346	-3.356*	69

*p<0.05

Table 6. Summary of statistics of independent sample t-test comparing mean scores of online survey responses with climate mean scores of UNFCCC negotiation participants with mean scores of non-participants on three risk perception indices: Risk Perception Index, Societal Risk Perception and Personal Risk Perception. M=Mean Score, SD=Standard Deviation, n=sample size, 95% CI= 95% confidence interval, t = critical t value, df = degrees of freedom.

Among participants of the UNFCCC negotiations (N=34), a one-way ANOVA indicated significant differences between different roles at the negotiations (diplomat (N=3), NGO representative (20), scientists (N=7), or other (N=4)) on Risk Perception Index ($F = 3.569$, $p = 0.027$), Societal Risk Perception ($F = 3.034$, $p = .044$) and Personal Risk Perception ($F = 3.232$, $p = .037$). Groups were too small to analyze specific group differences between roles at the UNFCCC negotiations. Among climate change professionals, a one-way ANOVA indicated no significant differences in mean scores on risk perception indices between different types of organizations (See Appendix V D). With regard to socio-demographic factors, no significant differences were found on all risk perception indices between male and female participants and correlations between age and all risk perception indices were not significant (see Appendix V C).

Because of the use of different scales, no comparison could be made between perceived likelihood of passing the Coral Reef Dieback and ASSI tipping points between climate change professionals or between survey format (online vs. paper-based). A Mann-Whitney U test indicated no significant differences between workshop participants and climate change professionals in perceived temporal distance of impacts of the Coral Reef Dieback ($U = 439.5$, $p = .259$), the WAIS ($U = 506.5$, $p = .579$), Boreal Forest Shift/Dieback ($U = 463.5$, $p = .477$) and ASSI ($U = 463.5$, $p = .144$) tipping points. In addition, when comparing between different types of survey formats, also no differences in perceived temporal distance of the four tipping points were found (Coral Reef Dieback: $U = 409.5$, $p = .880$, WAIS: $U = 419.0$, $p = .836$, Boreal Forest Shift/Dieback: $U = 369.5$, $p = .701$, ASSI: $U = 426.0$, $p = .644$). When comparing UNFCCC with non-participants, a significant difference was found in perceived temporal distance of the Coral Reef Dieback tipping point ($U = 323.0$, $p = .029$). This indicates that participants of the UNFCCC perceived the impacts of the Coral Reef Dieback as temporally closer compared to non-participants. No significant differences in perceived temporal distance were found for the other three tipping points (WAIS: $U = 510.0$, $p = .830$, Boreal Forest Shift/Dieback: $U = 451.5$, $p = .737$, ASSI: $U = 491.0$, $p = .598$).

With regard to within-subject differences, paired sample t-tests of combined survey data of online survey participants and workshop participants (N=78) revealed a significant difference between mean scores of Societal Risk Perception (M = 4.15, SD = 0.79) and Personal Risk Perception (M = 2.62, SD = 1.13) ($t(70) = 11.847$, $p < 0.001$), as illustrated in Figure 8.

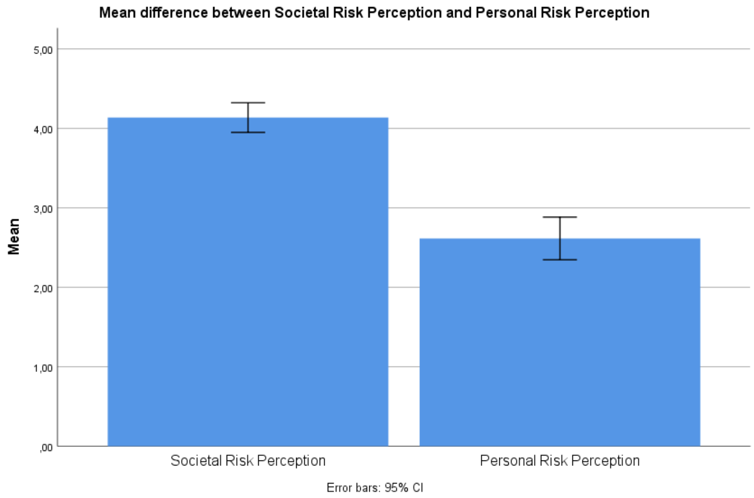


Figure 8. Mean scores of Societal Risk Perception and Personal Risk Perception, with 95% confidence intervals.

Significant higher levels of Societal Risk Perception compared to Personal Risk Perception were also found for climate change professionals only ($t(44) = 11.404$, $p < 0.001$) and workshop participants only ($t(25) = 5.335$, $p < 0.001$) and across survey formats (online survey: $t(52) = 10.505$, $p < .001$; paper-based survey: $t(16) = 5.151$, $p < .001$). The difference between Societal Risk Perception and Personal Risk Perception was larger among non-participants (M = 3.98 > M = 2.12, $t(29) = 10.235$, $p < .001$) compared to UNFCCC negotiation participants (M = 4.25 > M = 2.98, $t(40) = 7.497$, $p < .001$
As shown in Figure 9 and Table 7, differences were found in mean scores between different types of risks within Societal Risk Perception. A paired sample t-tests revealed that perceived risks regarding food and water security (M = 4.39) was significantly higher compared to risks to prosperity (M = 4.01) and risks to security (M = 4.04). No significant differences were found between perceived societal risks to prosperity compared to risks to security.

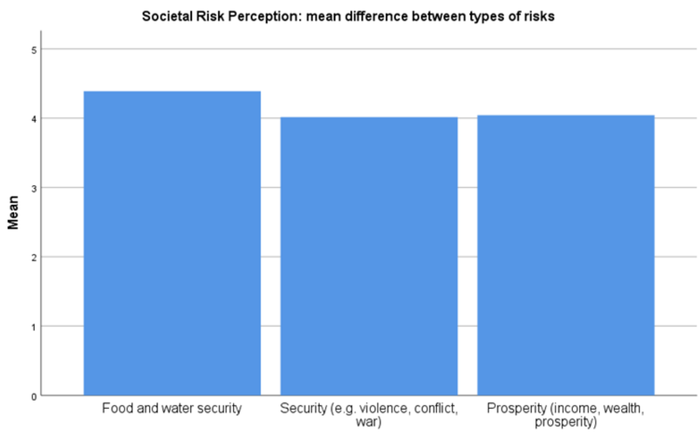


Figure 9. Mean scores of Societal Risk Perception: Food and water security, security and prosperity.

Comparison	Difference *M*	*SD*	95% CI for Mean Difference	*r*	*t*	*df*
(1) Food&Water, (2) Security	.375	0.863	.172, .578	.568	3.687*	71
(1) Food&Water, (3) Prosperity	.347	0.981	.117, .578	.478	3.004*	71
(2) Security, (3) Prosperity	-.028	.964	-.254, .199	.523	-.254	71

*p<0.05

Table 7. Summary of statistics of paired sample t-test comparing mean scores on risk perceptions of food and water security, security and prosperity within Societal Risk Perception. M=Mean Difference, SD=Standard Deviation of Difference, *r*= Pearson correlation , 95% CI= 95% confidence interval, t = critical t value, df = degrees of freedom.

As shown in Figure 10 and Table 8, within Personal Risk Perception, a small but significant difference between prosperity (M = 2.72) and security (M = 2.51) was found ($t(70) = -2.638$, $p = 0.01$).

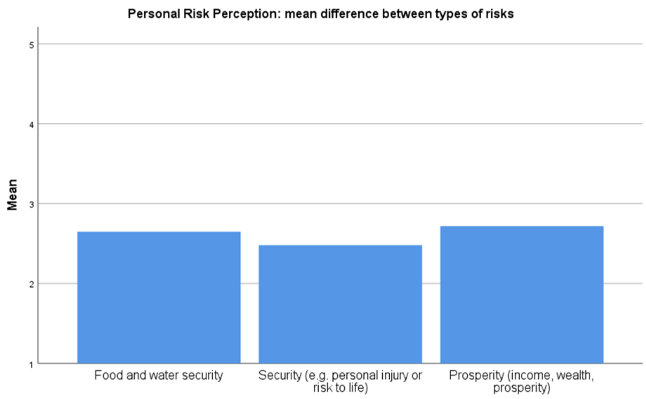


Figure 10. Mean scores of Personal Risk Perception: Food and water security, security and prosperity

Comparison	Difference *M*	*SD*	95% CI for Mean Difference	*r*	*t*	*df*
(1) Food&Water, (2) Security	.167	.856	-.0344, .368	.78	1.653	71
(1) Food&Water, (2) Prosperity	-.070	1.001	-.308, .167	.67	-.591	70
(1) Security, (2) Prosperity	-.239	.765	-.420, -.058	.81	-2.638*	70

*p<0.05

Table 8. Summary of statistics of paired sample t-test comparing mean scores on risk perceptions of food and water security, security and prosperity within Societal Risk Perception. M=Mean Difference, SD=Standard Deviation of Difference, *r*= Pearson correlation , 95% CI= 95% confidence interval, t = critical t value, df = degrees of freedom.

Within the merged survey responses (N = 78), participants reported higher risk perception ratings of risks of climate tipping points to other countries compared to risks to their own country (M = 4.51 > M = 3.75, $t(72) = 6.202$, $p<0.001$), as shown in Figure X. This effect was also found among climate change professionals only (M = 4.44 > M = 3.60, $t(44) = -5.118$, $p < 0.001$) and among workshop participants only (M = 4.61 > M = 4.00, $t(27) = -3.505$, $p = 0.002$) and among online survey responses (M = 4.39 >M = 3.59, $t() = -5.465$, $p < 0.001$) and paper-based survey responses (M = 4.83 > M = 4.28, $t(17) = -2.557$, $p = 0.02$). The difference in perceived risk for other countries compared to risks to participants' own country was also significant for participants of UNFCCC negotiations (M = 4.51 >M = 3.84, $t(42) = -5.465$, $p < 0.001$) for non-participants (M = 4.50 >M = 3.63, $t(42) = -5.465$, $p < 0.001$).

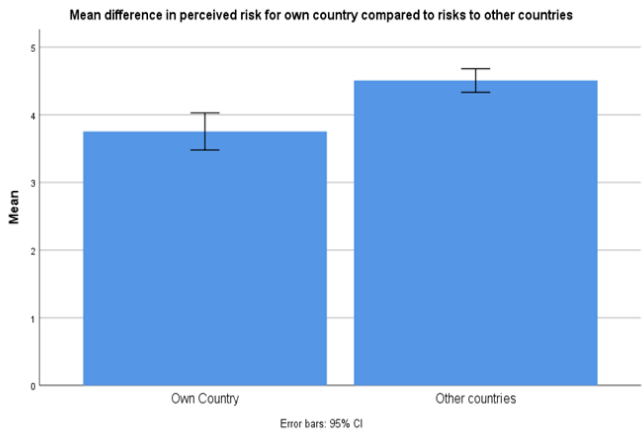


Figure 11. Mean scores of perceived risk of climate tipping points affecting participant's own country and mean scores of perceived of climate tipping points affecting other countries.

Among climate change professionals, no significant differences were found in mean perceived likelihood of Coral Reef Dieback tipping point (M=56.42, SD=29.18) compared to Arctic Summer Sea Ice tipping point (M=57.50, SD=27.13). Among workshop participants, mean ratings of perceived likelihood of passing the Coral Reef Dieback tipping point were significantly higher compared to perceived likelihood of passing the Arctic Summer Sea Ice tipping point (M=4.21>M=3.52, $t(25) = 3.333$, $p = 0.003$, SD=1.20). With regard to perceived temporal distance of impacts of the four tipping points, significant positive (Spearman's rank) correlations were found between perceived temporal distance of the WAIS, Boreal Forest Shift/Dieback and ASSI tipping points, as shown in Table 9. No significant correlations were found between perceived temporal distance of the impacts of the Coral Reef Dieback and the other three tipping elements (see Table 9)

Tipping Element	1	2	3	4
1. Coral Reef Dieback	---			
2. WAIS	.024	---		
3. Boreal Forest Shift/Dieback	.190	.427**	---	
4. ASSI	.191	.315*	.374**	---

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 9. Spearman's rank correlations between perceived temporal distance of the four tipping elements: Coral Reef Dieback, West-Antarctic Ice Sheet (WAIS), Boreal Forest Shift/Dieback and Arctic Summer Sea Ice (ASSI).

Perceived seriousness of the risks of climate tipping points correlated with perceived temporal distance of impacts of some but not all climate tipping points, as shown in Table 10. Perceived temporal distance of impacts of the WAIS and Boreal Forest Shift/Dieback tipping elements correlated significantly with several risk perception indices, in particular with societal risk perception.

Variable	Risk Perception Index	Societal Risk Perception	Personal Risk Perception
Coral Reef Dieback	-.087	-.004	-.020
WAIS	-.031	-.257*	.100
Boreal Forest Shift/Dieback	-.323*	-.391**	-.055
ASSI	-.097	-.206	-.057

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 10. Spearman's rank correlations between perceived temporal distance of the four tipping elements: Coral Reef Dieback, West-Antarctic Ice Sheet (WAIS), Boreal Forest Shift/Dieback and Arctic Summer Sea Ice (ASSI) and risk perception indices.

5.1.1.2 Perceived efficacy

With regard to perceived efficacy of influencing the likelihood of avoiding or triggering tipping points, within the merged survey data responses (N = 78), perceived collective efficacy was rated above medium (M = 4.37, SD = .879) and perceived personal efficacy (M = 3.13, SD=1.100) as well as efficacy of the UNFCCC community (M = 2.99, SD= 1.264) around medium levels on a 5-point Likert scale (for an overview of perceived efficacy items, see Appendix V B). Figure 12 shows the distribution of survey responses.

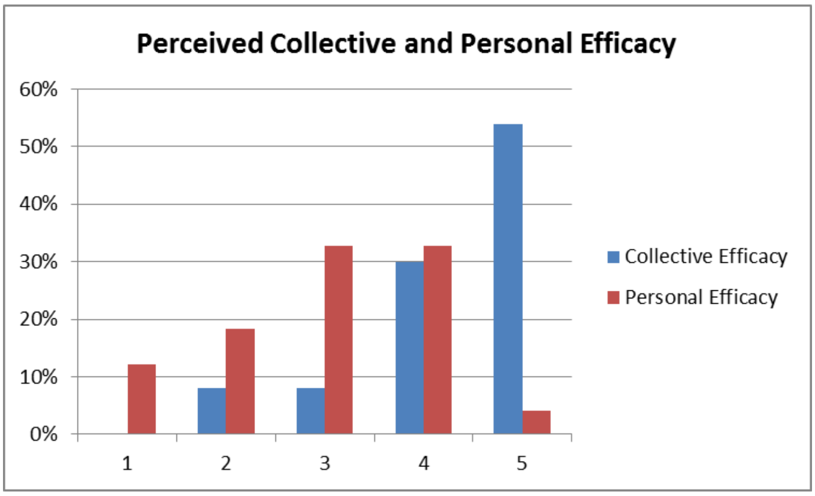


Figure 12. Distribution of responses (percentages) to perceived personal and collective efficacy, rated on a Likert-scale (1 = strongly disagree – 5 strongly agree)

With regard to the perceived efficacy of the negotiation community (i.e. level of agreement on the question whether the UNFCCC negotiation community knows how to respond effectively to climate tipping points), participants' responses varied (see Figure 13).

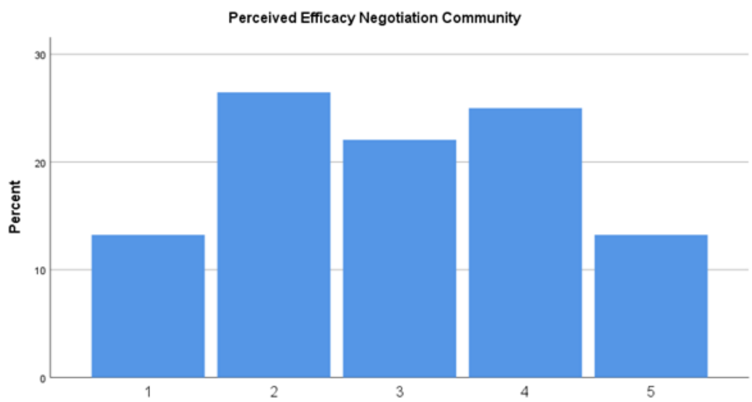


Figure 13. Distribution of responses (percentages) to perceived efficacy of the UNFCCC community, rated on a Likert-scale (1 = strongly disagree – 5 strongly agree).

Among the merged survey responses (N = 78), mean ratings of collective efficacy were significantly higher compared to mean ratings of personal efficacy (M = 4.37 > M = 3.13, $t(66) = 9.317$, $p < .001$), as shown in Figure 14. This difference was also found for climate change professionals only (M = 4.29 > M = 2.86, $t(41) = 7.7902$, $p < .001$) and workshop participants only (M = 4.52 > M = 3.60, $t(24) = 5.335$, $p < .001$). The effect was also found in only online (M = 4.31 > M = 2.98, $t(48) = 8.120$, $p < .001$) and paper-based surveys (M = 4.53 > M = 3.53, $t(16) = 4.408$, $p < .001$). The difference was also significant within participants of the UNFCCC negotiations (M = 4.54 > M = 3.31, $t(38) = 8.520$, $p < .001$) and non-participants (M = 4.14 > M = 2.89, $t(27) = 5.000$, $p < .001$).

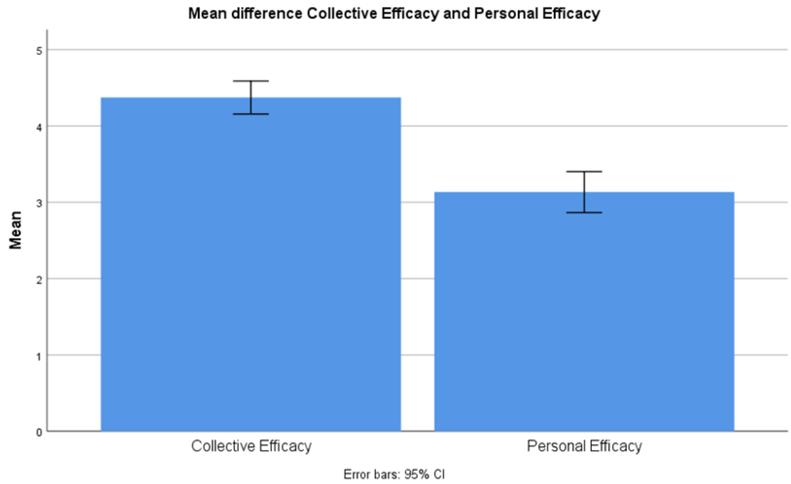


Figure 14. Mean scores of perceived collective efficacy and personal efficacy of influencing the likelihood of triggering or avoiding climate tipping points.

No significant difference was found between perceived personal efficacy and perceived efficacy of the UNFCCC community ($t(66) = .849$, $p = .399$). This result was consistent among climate change professionals ($t(41) = .343$, $p = .513$), across all online survey responses ($t(48) = -.447$, $p = .657$) and among climate change professionals that never attended any UNFCCC negotiation meeting ($t(27) = -.753$, $p = .458$). Perceived personal efficacy was significantly higher compared to perceived efficacy of the UNFCCC community among workshop participants ((M= 3.60, SD = .913 > M = 2.88, SD = 1.236), $t(24) = 2.688$, $p = .013$), across paper-based survey responses ($M = 3.53$, SD = 1.07 > M = 2.65, SD = 1.27, $t(2.667)$, $p = .017$) and across participants of the UNFCCC negotiations (M = 3.31, SD = .98 > M = 2.85, SD = 1.27, $t(38) = 2.070$, $p = .045$).

A Spearman's rank-order correlation analysis indicated multiple significant correlations between different perceived efficacy items (for an overview, see Appendix V E). A significant positive correlation was found between collective efficacy and personal efficacy among online survey and workshop participants combined ($r_s = .445$, $p < .001$, see Appendix V F), among workshop participants only ($r_s = .440$, $p = .028$) and among online survey participants only ($r_s = .466$, $p < .001$). In addition, perceived efficacy of the UNFCCC was positively associated with the belief that it's efficacy is dependent on a small number of important actors ($r_s = .365$, $p = .003$). Perceived personal efficacy correlated positively with (a) the belief that that their country is part of the group of important actors within the UNFCCC and (b) that their country is able to influence decision-making in this group (see Appendix V E). A strong positive correlation was found between a and b ($r_s = .697$, $p < .001$).

When comparing perceived efficacy between participants of the UNFCCC negotiations and non-participants, no significant difference was found for perceived collective efficacy ($t(66) = -1.793$,

p = .078), no significant difference for personal efficacy ($t(65) = -1.539$, $p = .129$) and no significant difference for perceived efficacy of the UNFCCC community. When comparing efficacy perceptions between workshop participants and climate change professionals, mean ratings of personal efficacy were higher among workshop participants compared to climate change professionals (M = 3.60 > M = 2.86, $t(65) = -2.811$, $p = .007$). No significant differences were found for collective efficacy and efficacy of the negotiation community. No significant differences in perceived efficacy between online survey and paper-based survey responses. Also, no significant differences were found between male and female participants and no significant correlations with age (see Appendix V G). A one-way ANOVA revealed no significant difference in perceived collective and personal efficacy between different types of organizations among climate change professionals and between different roles at the UNFCCC among participants of the UNFCCC negotiations.

5.1.1.3 Correlations perceived risk and efficacy

Among workshop and online survey participants, a Spearman's rank-order correlation analysis indicated significant positive correlations between risk perception (Risk Perception Index) and collective efficacy ($r_s = .266$, $p = .032$) and between risk perception and personal efficacy ($r_s = .349$, p = .005). In addition, personal risk perception was positively associated with personal efficacy (r_s = 348, p = .004), but not with collective efficacy (see Appendix V H). No significant correlations were found between societal risk perception and perceived personal and collective efficacy. Also, no significant correlations were found when only considering workshop participants or only online survey participants (see Appendix V H). Within personal risk perception, all three types of perceived risk (food and water security, security and prosperity) correlated significantly with personal efficacy (see Appendix V H). Among climate negotiation participants, personal efficacy correlated significantly with risk perception ($r_s = .371$, $p = .026$) and with personal risk perception ($r_s = .324$, $p = .048$). No significant correlations were found between risk perception and perceived efficacy among non-participants (see Appendix V H).

5.1.2 Qualitative results

5.1.2.1 Risk perception

Out of all responses of the question whether and why climate tipping points are important for policymakers (N=73), a majority (82%) of participants indicated that climate tipping points are important for policymakers (83% of workshop participants; 81% of climate change professionals) and a minority (8%) that they are currently not considered important by policymakers (7% of workshop participants; 9% of climate change professionals). The remaining share of participants indicated that the importance of climate tipping points depends on other factors including vulnerability and governance level and provided arguments against as well as in favor of their importance. However, many participants interpreted this question as whether and why climate tipping points *should* be important (or should be concerned) rather than whether and why they *already are* important (or are already concerned). A number of participants also stated specifically that policymakers should be concerned or aware about climate tipping points, although they are currently not. Hence, the arguments that participants provided were about why policymakers are OR should be concerned about climate tipping points ('important' group) and why policymakers are currently not concerned about climate tipping points ('not important' group). The arguments provided by participants were further categorized (see Appendix VI B;C for codebook) in the three risk perception categories (uncertainty/likelihood, seriousness of impacts and perceived temporal distance).

Among participants that argued that policymakers are or should be concerned about climate tipping points (N=60), 10% of arguments were about the likelihood of passing tipping points and uncertainty in thresholds and 47% with seriousness of impacts of climate tipping points (see Appendix VI B). No arguments relating to temporal distance were observed within this group. Within the argument relating to impacts of climate tipping points, participants indicated that tipping points should be important because they could result in irreversible system changes (e.g. "Important because the system changes rapidly and irreversibly", "would change system dynamics") and catastrophic impacts (e.g. "they will have major impacts on society and human wellbeing", "will have dramatic impacts on human populations"). A further distinction could be made regarding the type of impacts participants referred to (see Appendix VI D). Impacts most commonly referred to were changes in system dynamics, socio-economic impacts (including inequality in access to food and water, economy, peace and poverty) and impacts to human wellbeing in general.

Additional argument categories that were revealed were that climate tipping points are important because they emphasize the urgency of early action, because they guide policymakers in decision-making on climate change, because they are related to global temperature increase and more generally because of moral obligations or standards (see Appendix VI B). Within statements regarding emphasis of early action, two different lines of argumentation were revealed: (1) climate tipping points emphasize early action because later action might less effective and/or more costly and (2) climate tipping points emphasize early action because they show consequences of policy inaction (see Appendix VI D). The most common reasoning related to the argument that tipping points guide policymaking was that tipping points guide in the formulating policy goals (see Appendix VI B). The most common underlying reason behind the argument concerning uncertainty and likelihood of thresholds of climate tipping points were that this uncertainty calls for a precautionary approach in climate policy (see Appendix VI C).

Among participants in the 'not important' group, the most common argument was related to temporal distance of climate tipping points (e.g. "the problem is that it is all very abstract, and therefore unlikely to lead to meaningful change in time", "not sure that the policy-makers are interested in tipping points, except if we can proof that they will happen within their term of office"). Additional arguments posed by multiple participants were concerned with the current lack of knowledge of climate tipping points among policymakers and that other important issues compete for political attention. One participant indicated that policymakers might be overconfident in the possibility to adapt to climate tipping points and another participant highlighted that implying certainty about climate tipping points might negatively impact the science-policy dialogue.

Based on the findings of qualitative analysis regarding arguments and sub categories, a framework was created that indicates underlying reasoning of whether climate tipping points are or should be important for policymakers and underlying reasoning why climate tipping point are currently not considered by policymakers, which is shown in Figure 15.

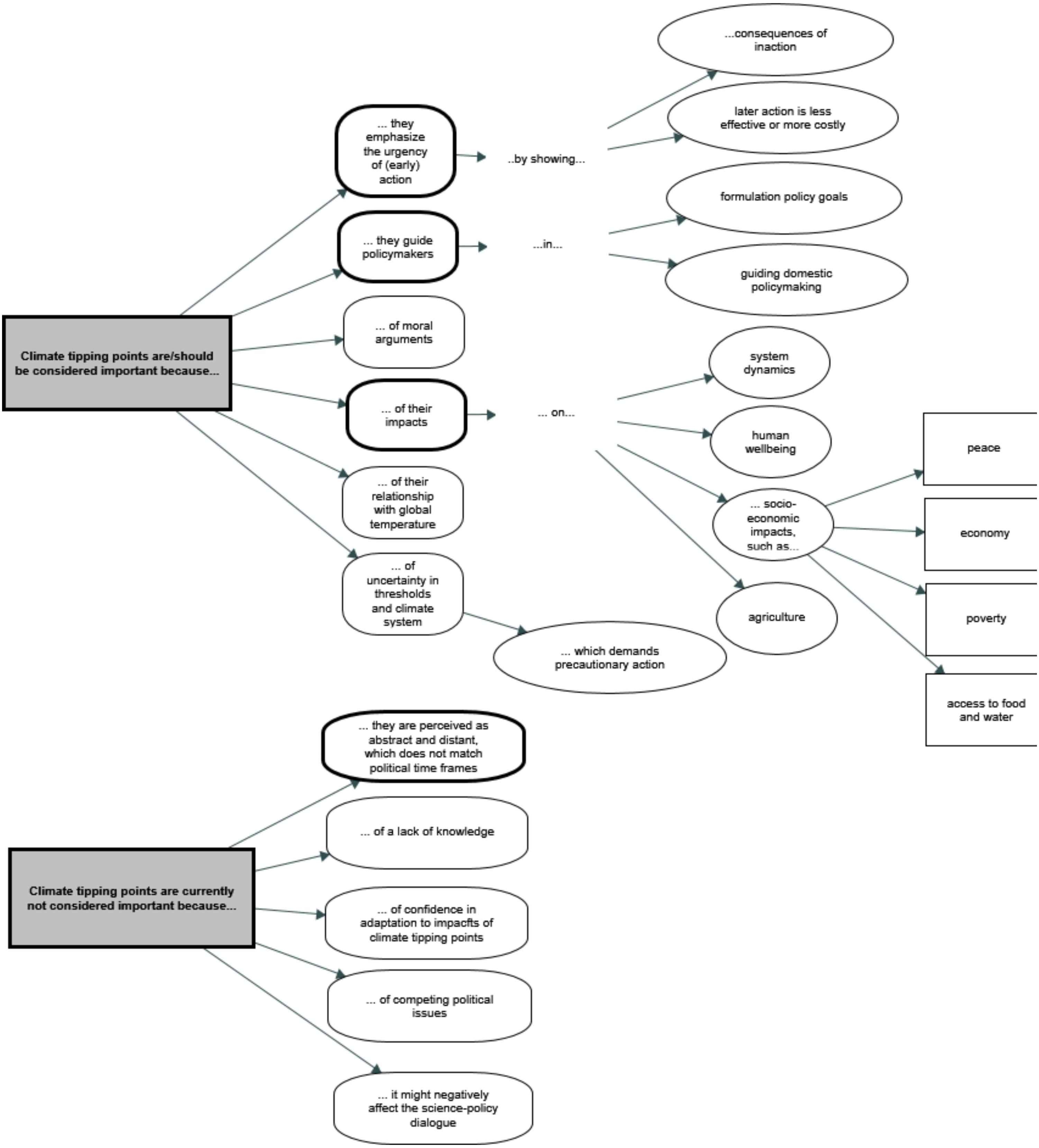


Figure 15. Framework of arguments provided by participants in 'important' (climate tipping points are or should be important for policymakers) and 'not important' groups. Thick lines show the most common arguments provided by participants.

5.1.2.2 Perceived efficacy

A minority of study participants (15%) provided comments on the efficacy items. Nevertheless, some arguments concerning (lack of) collective efficacy, efficacy of the UNFCCC community and country-efficacy could be identified. With respect to collective efficacy, one study participant indicated that issues of level playing field reduce the likelihood of collective action towards climate tipping points (see Appendix VI G). Other participants indicated that uncertainty in the climate system and a lack of scientific understanding of this hampers governance responses to climate tipping points because it makes it difficult to know how to respond. Statements concerning efficacy at the national level were concerned with the lack of influence of individual countries on global climate politics and the issues hampering the speed and success of national climate policy (i.e. politicization of climate issues).

5.2 Effects of the role-playing simulation game

5.2.1 Quantitative results

A total of 10 workshop participants filled in both the pre- and post-workshop surveys. Therefore, quantitative analysis of changes in perceived risk and efficacy items was only performed for this small group. With such a small group, findings significant differences is very unlikely. However, paired-sample t-tests were still performed in order to find effects.

5.2.1.1 Difference in risk perception

Comparing survey responses between pre- and post-surveys did not reveal significant differences between mean risk perception (Risk Perception Index) and societal risk perception, but differences in personal risk perception were significant (M = 4.259 > M = 3.667, $t(9) = 2.340$, $p = .047$) (See Appendix V K). When comparing pre- and post-workshop survey responses on each risk perception item individually, only societal risk perception regarding prosperity specifically was rated higher in pre-workshop surveys compared to post-workshop surveys (M = 4.44 > M = 3.56, $t(9) = 4.438$, $p = .002$).

5.2.1.2 Difference in perceived efficacy

No significant differences were found on perceived efficacy items when comparing pre-workshop with post-workshop survey responses (see Appendix V L).

5.2.2 Qualitative results

5.2.2.1 Changes in risk perception

Observational notes of the four observers of the debriefing session indicated that across all three workshop sessions, most workshop participants were more concerned about climate tipping points after participation in the Tipping Point Negotiation game (see Appendix VI I). Interobserver agreement appeared high (no statistic calculated, but see Appendix VI I). More specifically, during the first workshop session with NGO representatives, all participants indicated to be more concerned. During the second (NGO representatives) and third workshop session (diplomats), a majority of participants indicated to be more concerned, except a few who reported no change.

Additional learning experiences that participants shared during the debriefing sessions (derived from observational notes) and post-survey responses of the three workshops revealed insights in changes in risk perceptions as well. A number of participants indicated that the Tipping Point Negotiations game made climate tipping points more tangible and concrete (see Appendix VI H), which indicates the game might have changed perceived distance of climate tipping points. Furthermore, statements during the debriefing session suggested that the game changed perceptions about risks of climate tipping points to their personal life (N=2). Other learning experiences concerning risk perceptions were that the game increased awareness of specific risks associated with climate tipping points (N=1) and about the uncertainty of climate tipping points (N=1).

5.2.2.2 Changes in perceived efficacy

Observational notes during the debriefing indicated that the game did not result in an increased perceived efficacy regarding passing or triggering climate tipping points. In the first workshop (NGO representatives), participants reported no difference or a decreased sense of agency/perceived efficacy after engaging in the role-playing exercise, yet an increased sense of what can be done to prevent passing points. However, observational notes of the second workshop (NGO representatives) revealed that participants reported no difference in knowing what can be done. In the third workshop (diplomats), observational notes revealed statements of participants regarding country-specific efficacy; some participants indicated that governance response options are country-dependent based on their vulnerability, resources and political system (see Appendix VI J). All in all, although no specific changes in perceived efficacy as a result of the Tipping Point Negotiations game could be identified, the game might have induced an increased sense of urgency of appropriate governance responses in a more general sense, based on participants' experiences (e.g. "the simulation solidified that we really have one shot to do this right"). In the observational notes on learning experiences, no information on changes in perceived efficacy were identified.

6. Discussion

The Gaming Climate Futures project is aimed at analyzing the understanding of climate tipping points within the climate negotiations community and deepening this understanding by means of a role-playing simulation game, in which climate negotiators explore the relationship between global temperature goals and climate tipping points and imagine climate futures following a collective decision-making process. As part of this project, the current research specifically focused on risk and efficacy perceptions among participants of international climate negotiations and other climate change professionals, and the effects of the game that was developed in the project on these perceptions. Thereby, the present research was the first to study perceptions of risks associated with climate tipping points and perceived efficacy of influencing the likelihood of climate tipping points among participants of UNFCCC negotiations. Therefore this research adds to literature on the role of cognition in global climate governance and the role of perceptions in global climate negotiations specifically (e.g., Milkoreit, 2013; 2015; 2017), to research on perceptions of climate tipping points specifically (Bellamy & Hulme, 2011) and to literature on risk and efficacy perceptions associated with climate change more generally (e.g. Bostrom et al., 1994; Leiserowitz, 2006, Spence et al., 2012). The Gaming Climate Futures project is first-of-its-kind in studying cognitive changes and political dynamics following a serious game among climate negotiators, making the present research novel in studying effects of a serious game on risk and efficacy perceptions associated with climate tipping points, which contributes to the understanding of the role of serious gaming in bridging the science-policy gap in global climate governance (Haug et al., 2011; Milkoreit, 2015). First, the most important findings of this research will be discussed, followed by a more detailed elaboration on the results (section 6.1). Thereafter, limitations will be discussed (section 6.2), followed by recommendations for future research and game design in the context of global climate governance (section 6.3).

6.1 Discussion of results

A majority of study participants of the current study, i.e. professionals that are actively working in the field of climate change and UNFCCC negotiation participants, perceived the risks associated with climate tipping points as highly serious, in particular the risks to society as a whole. None of the study participants expressed no concern about climate tipping points, the majority being concerned to extremely concerned. These findings are in line with Bellamy & Hulme (2011), who demonstrated high concern of abrupt climate change. As expected, the perceived ability of humanity to influence the likelihood of triggering or avoiding climate tipping points (i.e. collective efficacy) was high among study participants. This is in accordance with previous research suggesting that climate negotiation participants are generally optimistic about the collective ability of humanity to develop solutions to climate change (Milkoreit, 2017). Perceived efficacy of influencing the likelihood of triggering or avoiding climate tipping points by means of individual actions (i.e. personal efficacy) was relatively low, which also matched expectations, considering that climate change action involves large-scale collective action. It was further expected that perceived efficacy of the UNFCCC was relatively high compared to personal efficacy, given that the collective ability of the UNFCCC to influence climate change surpasses individual abilities. Surprisingly however, study participants were not particularly convinced of the current level of understanding of the climate negotiation community in developing appropriate governance responses to climate tipping points. This result may be explained by more general doubts about the speed and effectiveness of the UNFCCC among climate negotiation participants (Milkoreit, 2017). Hence, there seems to be a mismatch in risk perception (high perceived seriousness and high concern) and perceived efficacy (low perceived efficacy of the climate negotiation community). Moreover, considering previous research regarding the lack of knowledge about climate tipping points in the climate negotiation community (Milkoreit, 2015), one may argue a second mismatch appears between (high) risk perception and (lack of) knowledge.

Although quantitative differences were inconclusive due to small sample sizes, qualitative analysis indicated that the role-playing simulation game used in the current study increased concern about climate tipping points among UNFCCC negotiation participants. In line with existing literature (e.g. Chittaro & Sioni, 2015; Rebolledo-Mendez et al., 2009), this research supports the potential of serious games in affecting risk perceptions, and provides insights in how serious games might change perceptions of climate change risks. In particular, participants indicated that engaging in the role-playing simulation game made the risks of climate tipping points more concrete and personal, implying changes in perceived distance and perceived personal risk. Against expectations, no changes in perceived efficacy were observed in the current study. This is conflicting with previous studies (Chittaro, 2012; Tanes, 2017), which might be explained by differences in types of risks and types of perceived efficacy under study. Nevertheless, this result suggests that exploring consequences of negotiated decisions on climate change mitigation and adaptation on passing tipping points might not be effective in changing perceived efficacy of influencing the likelihood of climate tipping points. Although the game showed consequences of collective decisions on the likelihood of passing tipping points and enabled the imagination of long-term possible futures, the game might have been limited in the exploration of response options and therefore might not have changed perceptions about which actions could or should be taken (hence no change in perceived efficacy of those actions).

A more detailed discussion of findings of risk and efficacy perceptions and underlying factors are now discussed. A majority of study participants seemed to be aware of the catastrophic and irreversible impacts of climate tipping points and this was a dominant argument among participants regarding why tipping points are important for global policymakers. Given that the catastrophic impacts of climate tipping points were indicated as underlying reasoning for concern in previous research (Bellamy & Hulme, 2011), the awareness of those impacts among study participants might explain the relatively high perceived seriousness of risks and high concern among study participants. With regard to differences in perceptions of different types of risks, risks to society were perceived as more serious compared to risks to personal life, in accordance with previous research (Bord et al., 1999, Van der Linden, 2015). Within risks perceived for society, risks to food and water security were perceived as more serious compared to risks to prosperity and risks to security and within perceived personal risks, risks to prosperity were perceived as more serious compared to risks to security. These findings suggest that within risk perceptions of climate tipping points, there are crucial differences in the way risks to personal life as opposed to risks to society are perceived, which supports Van der Linden's (2015) argument that societal and personal risk perception might be influenced by different socio-cognitive factors. Furthermore, consistent with existing literature (Bellamy & Hulme, 2011; Maibach et al., 2008; Spence et al., 2012) and expectations, study participants perceived risks to their own country as less serious compared to risks to other countries. Some might consider this surprising because impacts of several climate tipping elements are much more spatially specific (e.g. coral reef dieback) than climate change in general. However, this perceived spatial distancing effect might be the result of the self-selection bias of participants; not representing a fair distribution of nationalities and global regions.

With regard to perceived temporal distance, if we were to pass climate tipping points (i.e. Coral Reef Dieback, Boreal Forest Shift/Dieback, West-Antarctic Ice Sheet and Arctic Summer Sea Ice), a majority of the participants expected impacts on the short-term (immediately or within a few years) or medium-term (within a few decades). This suggests that climate tipping points are not perceived as temporally distant by study participants, which is in contrast to previous research (Bellamy & Hulme, 2011). This might be explained by differences in public perceptions compared to perceptions of participants of climate negotiations and other climate change professionals. This particular group might be more aware of the risks associated with climate tipping points and might perceive them as temporally closer. However, another explanation might be the difference in measuring perceived temporal distance; Bellamy and Hulme (2011) asked participants to indicate which of the tipping points they perceived as likely to occur in 50 years from now whereas in the current study participants were asked to rate perceived temporal impacts of tipping points, given that they have been passed. Many study participants argued that although climate tipping points should be important, they are currently not considered important by global policymakers. The dominant argument provided by participants was that climate tipping points are perceived as distant, happening on the long-term, incongruent with political time frames, which conflicts with earlier findings that only a minority of participants expected impacts on the long-term (i.e. a century). However, in the current study medium-term temporal distance indicated a few decades, which is still well outside political timeframes. Thus, this result emphasizes that the meaning of 'distant' or 'long-term' is subjective and depends on the relative time frames under study. In the present study, impacts of the Coral Reef Dieback were perceived as temporally closer compared to the other three tipping points by UNFCCC negotiation participants. A possible explanation for this finding is that negotiation participants are more aware of this tipping element. This also suggests that risk perceptions (including perceived likelihood and temporal distance) might differ between different tipping elements, which was also suggested by Bellamy & Hulme (2011).

Furthermore, results of the current research revealed that participants of the UNFCCC negotiations perceived risks of climate tipping points as more serious compared to non-participants, particularly risks to their personal life. One may argue this is the result of higher involvement in global climate change politics, although this effect may have been caused by self-selection bias and the interviewer effect (see section 6.2). In addition, the data revealed differences in risk perceptions between different roles of participants at the UNFCCC negotiations, although sample sizes were insufficient to compare groups. Among climate change professionals, no differences in risk perceptions were found between different types of organizations. Results of the current study indicated no relationship between risk perception and gender and age, supporting earlier research that socio-demographic factors are negligible factors explaining perceived risk (Van der Linden, 2015). In addition, a positive relationship was found between risk perception and perceived efficacy, consistent with existing literature (e.g. Milfont, 2012; Reser et al., 2012).

Further analysis of perceived efficacy revealed further insights in relationships between different efficacy perceptions and insights in possible underlying factors of (lack of) perceived efficacy. Analysis of survey responses revealed positive relationships between multiple perceived efficacy items. Respondents that perceived high levels of collective efficacy were also likely to perceive high levels of personal efficacy and high levels of efficacy of their own country to influence the likelihood of avoiding or triggering climate tipping points. This suggests when perceived collective efficacy is enhanced, this might also enhance perceived personal efficacy and efficacy of people's own country. This is an important finding, as it implies that when negotiation participants are convinced of the collective ability of humanity to influence the likelihood of avoiding climate tipping points, this might enhance perceived efficacy of their influence on the decision-making of other negotiation participants, which in turn could influence their political decision-making (although this influence might be small and findings of the current research are limited in drawing conclusions on this).

With regard to collective action regarding governance responses to climate tipping points, participants indicated that this may be hampered by uncertainties in the climate system and a lack of scientific understanding of climate tipping points. Thus the scientific uncertainty might not only be an underlying reasoning of risk perceptions of climate tipping points (Bellamy & Hulme, 2011), but of efficacy perceptions as well. This finding might have implications for the role of uncertainty of thresholds in promoting cooperation (Barrett & Dannenberg, 2012; 2014) and the role of early warning of climate tipping points in risk reduction strategies (Lenton, 2011) in global climate governance (see section 6.3.2). In addition, study participants argued that contributions at the country level may further be hindered by a lack of power and influence on global climate politics and politicization of the climate change on the national level. On top of that, participants seemed to doubt the efficacy of the climate negotiation community to formulate appropriate governance responses to climate tipping points. Based on research that overall perceived capability of the group in performing a broad range of tasks (i.e. group potency) is highly related to perceived group efficacy of a specific task (Gibson & Early, 2007; Gully et al., 2002), this finding raises questions regarding the perceived (group) efficacy of the UNCCC in general. After the lack of success of the Copenhagen Agreement in 2009 in agreements on legally binding commitments, negotiation participants were doubtful about the speed and effectiveness of the UNFCCC (Milkoreit, 2015). Results of the current study point to the direction that this belief might still exist, even after realization of the Paris Agreement in 2015. The lack of perceived efficacy of the UNFCCC is also in sharp contrast with arguments provided by study participants regarding why climate tipping points should be important for global policymakers; because they emphasize early action and guide policymaking in terms of formulating policy goals. This suggests that although climate tipping points could indeed create a sense of urgency and guide decision-making in global climate negotiations (Galaz, Biermann, Folke et al., 2012), the understanding of climate tipping points within the UNFCCC and in particular, an understanding of appropriate governance responses might indeed still be lagging behind, as was suggested by Milkoreit (2015). This will be further elaborated on in section 6.3.2.

6.2 Limitations

Some caution should be taken when drawing conclusions from the results of the current study, taking into consideration various limitations. As previously discussed, at least two biases might have influenced the results of the current study; self-selection bias (Riva et al., 2003) and the interviewer effect (Duffy et al., 2005). With respect to the former: participants (both workshop participants and climate change professionals) are not random selected samples of the target population, but are self-selected as they were invited to participate and might therefore be an adequate representation of the target population. For example the level of concern might be overestimated in the current study, as individuals that are highly concerned about climate tipping points might be more likely to be motivated to participate in the workshops or online survey among climate change professionals. Moreover, although the survey link was spread among networks of climate change professionals only, individuals that do not meet characteristics of this target groups might still have filled in the survey because of a lack of control on survey completion. With regard to the interviewer effect: survey responses of participants that filled in surveys at the workshops in Bonn might be more socially desirable because of the presence of the project team members or other participants of the workshops, compared to responses of online survey participants. For example, paper-based survey participants might have reported higher levels of concern about climate tipping points than they actually are. Indeed, results of the current study revealed higher ratings on multiple risk perception items among paper-based compared to online survey participants (see Results). However, within-subject differences in risk perception and perceived efficacy were found in both types of survey formats, which legitimizes merging the survey data.

Another issue that might have influenced the results is the use of different target populations (i.e. workshop participants that are NGO representatives or diplomats that were attending UNFCCC SB48 and professionals that actively work in the field of climate change). Climate change professionals are a broad target group involving a much wider population than the participants of the workshops, which might result in differences in perceptions. Indeed, some differences were found when comparing those groups, although within-subject differences were found across groups (see Results). Moreover, the distinction between UNFCCC negotiation participants (including also climate change professionals that attended one or more UNFCCC meetings in the past) and non-participants might not have been adequate. It was assumed in the current study that climate negotiation participants are more actively involved in global climate politics compared to non-participants, although one may argue that participating in a UNFCCC meeting a long time ago might not account for this. In addition, the number of diplomats in the current research was too small to draw conclusions on perceptions of this particular group. Therefore, results of the current research remain inconclusive regarding perceptions of actual climate negotiators (i.e. diplomats that represent UNFCCC nations), which might be different from negotiation participants in general (with different roles at the negotiations) considering high relative influence and power of diplomats in global climate politics. Besides that, in the present research revealed only a few underlying factors of risk and efficacy perceptions associated with climate tipping points, largely because of limitations in data, for example no open question specifically addressed risk perceptions and insights in perceived efficacy were based on only a few comments of participants. Results of the current study were also inconclusive regarding differences in perceptions between individuals with different nationalities, which might vary based on vulnerability or experience with climate change impacts (e.g. Brody et al., 2008; Spence et al., 2011) and differences in resources and power (e.g. Milkoreit, 2017).

Various limitations should also be considered regarding the effects of the role-playing game on perceptions of climate tipping points. Due to a low response rate of post-workshop surveys, direct comparison of pre- and post-survey responses was limited to ten participants and quantitative results were therefore inconclusive. A second important limitation of the present research was that the time frames and survey formats of completion of the pre-workshop as well as the post-workshop surveys differed between participants (pre-workshop: online surveys up to two weeks online or paper-based directly before workshops, post-workshop surveys: up to four weeks after the workshops). Risk perceptions might change over time and therefore, this might have influenced the results. For example, the risks of climate tipping points might have been particularly salient among participants directly after the workshop sessions, which might have reduced slightly over time. Although long-term effects are important to analyze, in the current research no distinction can be made between direct and longer-term effects on perceptions because of the differences in time frames. Also, the context in which the online surveys was not controlled, which might have influenced results as well as potential influences of the survey format, as previously discussed.

In addition, with regard to data from the observational notes, observers may be biased in their interpretation of statements and actions of participants. In addition, the present research is limited in drawing conclusions on effectiveness in changing perceptions compared to traditional learning methods and how the game might affect different target groups. In addition, success or failure in the game might have influenced perceptions, particularly perceived efficacy (Bandura, 1998) of influencing the likelihood of climate tipping points. When players of the Tipping Point Negotiations game put much effort in trying to avoid climate tipping points, for example by contributing a large share of their budgets to climate change mitigation and trying to convince other player to do the same, but multiple tipping points were still passed, their belief in their own and collective capability to avoid climate tipping points (i.e. perceived efficacy) might be reduced after playing the game. In addition, it is still unknown how different levels of uncertainty regarding the thresholds of the tipping elements influence the behavior of players in this game, which has been suggested to influence cooperation (Barrett & Dannenberg, 2012; 2014). Importantly, the results of the current study only provided insights in relatively short-term cognitive changes; long-term effects on political decisions and behavior, particularly among climate negotiators are still unknown. However, this will be addressed by other researchers in the Gaming Climate Futures project.

6.3 Recommendations

6.3.1 Recommendations for future research

Considering the limitations and possible biases in data collection of the current research, future research is needed that further explores risk and efficacy perceptions associated with climate tipping points and the effects of a role-playing simulation game in changing these perceptions. Biases such as self-selection bias and the interviewer effect should be avoided as much as possible by improving data collection; using larger sample sizes and better defined target groups while controlling for potentially influencing factors such as the survey format and the context in which the survey is completed. It also remains largely unknown how other factors relate to risk and efficacy perceptions associated with climate tipping points, such as knowledge (especially since contrasting results have been found in literature; e.g. Kelldstedt et al., 2008; Kahan et al., 2011) and emotions (especially how different perceptions are related to different types of emotional responses, building on Milkoreit, 2017 and Stevenson et al., 2015). Besides, the influence of socio-demographic and socio-cultural factors remains unclear, such as nationality (which might be different considering vulnerability to impacts of climate tipping points, resources and power), value orientations (e.g. Kellstedt et al., 2008; Milfont, 2012; Van der Linden, 2015) and cultural worldviews (e.g. Kahan et al., 2011; 2012; Shi et al, 2015). Considering that the risks associated with climate tipping points might be perceived differently than climate tipping points in general (Bellamy & Hulme, 2011), future research should address these factors as well as revealing additional factors that have not yet been addressed in literature. This would contribute to a better understanding of risk and efficacy perceptions and which would would reveal valuable insights in the development of strategies aimed at influencing these perceptions. Based on the results of the current study, it is recommended that future research on risk perceptions associated with climate tipping points distinguishes between societal and personal risk perception, risks perceived to participants' own country versus other countries and incorporating multiple risk perception elements including perceived likelihood and temporal distance while distinguishing between the different tipping elements (see for example Bellamy & Hulme, 2011). With regard to perceived efficacy, future research should distinguish between personal and collective efficacy. Also, building on Katsaliaka & Mustafee (2014) it might be important to distinguish between perceived ability to perform certain actions (i.e. perceived efficacy) and perceptions of those actions on avoiding climate tipping points (i.e. outcome expectancy) as this might have different implications for motivations or political decision-making in social dilemma situations.

Furthermore, although the observational notes provided some preliminary insights in overall effectiveness of the role-playing simulation game in terms of changes in risk and efficacy perception, future research is needed that provides a more elaborate understanding of the game effects. It is recommended that future research addresses some limitations of the methodology of the current study by increasing sample sizes and by using pre- and post-workshop surveys of similar formats that are completed at the same time by all participants; preferably directly before and after the workshops. This provides a better understanding of the changes in perceptions that can actually be attributed to participation in the workshops. In order to reveal benefits of the use of serious gaming compared to traditional learning methods, future research should compare the game with a learning experience with similar but not game-like features, although this might be challenging in practice. In addition, additional cognitive changes might be important in understanding belief systems of climate negotiators, of which some are addressed by other researchers in the Gaming Climate Futures project; different types of knowledge and future thinking. Other changes may also be further explored in future research, such as emotional responses or social learning, that might be important considering long-term effects on political decision-making. Furthermore, as the level of success and failure in avoiding climate tipping points might influence efficacy perceptions, future research should further explore this. Related to this, building on research by Barrett and Dannenberg (2014), the influence of different levels of uncertainty on success or failure in this game might be further explored in future research as well. Additional questions that remain unanswered in the present research are: What elements of risk perception changed as a result of the game (e.g. perceived likelihood, perceived temporal distance, types of risks that participants are aware of)? Are the changes in perceptions caused by other cognitive or emotional changes, e.g. affect, imaginative personal experience, etc.? What game elements contributed to changes in perceptions of risks? Why does the game not change perceived efficacy of influencing climate tipping points or an understanding of possible governance responses?. With regard to the second question, different versions of the role-playing game could be used with varying elements in order to find effects of particular elements of the game. However, considering the multitude of elements in the game, this might not be feasible or efficient. Furthermore, the effects of the role-playing simulation game are limited to a specific target group; future research should analyze the effects using other target groups to see if there are differences in results in order to understand its applicability to other actors that might be of importance in global climate governance, such as international organizations or the private sector.

Importantly, future research is needed that investigates risk and efficacy perceptions of climate negotiators (diplomats) specifically, using a larger sample size than the current study, in order to obtain further insights in their (lack of) engagement with climate tipping points and the possible political implications of those perceptions. In particular, future research should investigate differences in perceptions of climate tipping points compared to climate change in general within this particular group, building on findings by Bellamy and Hulme (2011). This would contribute to the understanding of communication of climate science and scientific insights of climate tipping points specifically and the way this informs political decision-making. This would also have implications for the debate on the normative notion of climate tipping points or abrupt climate change more generally, and how this might influence political action (Galaz, Berimann, Crona et al., 2012; Gardiner, 2009; Russil & Nyssa, 2009). With regard to the finding that participants were not convinced of the efficacy of the UNFCCC to develop appropriate governance responses to climate tipping points, further research should investigate what the underlying reasons are behind those perceptions. One possible explanation is that the climate negotiation community lacks understanding of climate tipping points (Milkoreit, 2015). Other explanations might be doubts about the speed and effectiveness of the UNFCCC or the negotiation stance of the United States (Milkoreit, 2017). In Milkoreit's (2017) study, these doubts may have resulted from limited success in the Copenhagen Accord in 2009 and at the time of writing (2018), the negotiation stance of the United States is under pressure again since their withdrawal from the Paris Agreement in 2017. Therefore, future research should not only investigate perceived efficacy among climate negotiators of the UNFCCC in developing governance responses to climate tipping points, but also efficacy of this community to address climate in principal, as well as other potential influences that might be of importance. In particular, the effects of a role-playing negotiations game on perceptions of actual climate negotiators should be addressed in future research, because this might reveal insights in the communication of climate science and the role of serious gaming in bridging the science-policy gap in global climate negotiations (Milkoreit, 2015). This would improve the understanding of the risks of how climate tipping points, and particularly the uncertainty associated with them, should be communicated in global climate negotiations and the role of serious gaming in this communication. Building on Social Cognitive Theory positing that collective efficacy influences the types of goals that are collectively desired, the types of pathways towards these goals and individual commitments towards these goals (Bandura, 1998; 2000), future research might further explore the relationship between collective efficacy (of the UNFCCC) and aspirations for different (1.5°C or 2°C) global temperature goals. Given Bandura's (1998) suggestion that high perceived efficacy promotes the visualization of positive scenarios, future research may also focus on this relationship among climate negotiators, as this may influence their future thinking (in particular the ability to imagine long-term futures; Milkoreit, 2015).

In a more general sense, although some researchers are exploring this (Bosetti et al., 2017 and Milkoreit, 2013; 2015; 2017), the cognitive processes and belief systems of climate negotiators is a largely unexplored area of research, despite the relatively large influence of their political decisions. Therefore, the current research emphasizes the need for future research that further explores this. The current research demonstrates that cognitive science research can reveal insights in the understanding and perceptions of climate science within the climate negotiation community, which might be valuable in the understanding of their political decision-making (yet considering this as part of a broader set of interacting factors influencing decision-making). Research that combines environmental governance with cognitive science research is currently lacking, with only a few researchers that have addressed this so far. Therefore, this is an important research field that deserves more attention. Furthermore, although results of the current research can be seen as preliminary considering the limitations, the current research supports the potential of serious gaming and in particular role-playing simulation games as science-policy interface. It is therefore recommended that future research further explores this potential.

6.3.2 Recommendations for game design in the context of global climate governance

Based on the insights revealed in the current study, some recommendations can be drawn concerning game design in general, the role of perceptions of climate tipping points in global climate governance and how a serious game can be designed that addresses this. With regard to game design in general and design of climate change games in particular, the literature review on learning effects of serious gaming revealed insights in important game elements that might improve effectiveness. For example, researchers have emphasized the importance of providing immediate feedback (e.g. Cameron & Dwyer, 2005) and including surprise events (Wouters et al., 2013). Experiences of the Tipping Point Negotiations game revealed that real-time insights in the effects of decisions on global temperature and the likelihood of passing tipping points might indeed be important in order to improve the understanding of this relationship. Surprise events such as the event cards in this game might also have been important for the learning experience, particularly in keeping participants focused and emotionally engaging them in the issue at stake. Furthermore, serious games might be most effective when combined with other instruction methods (Stizmann, 2011), such as providing a lecture or presentation prior to the game, which was done in the workshops of the Gaming Climate Futures project. The effects of the presentation alone were not investigated in this project, but considering that participants lacked overall understanding of climate tipping points, this presentation seemed crucial for the learning process.

Another interesting finding in previous literature is that a more realistic game is not necessarily better; it might not be more effective in terms of cognitive outcomes (Wouters et al., 2013), although it has been proven to beneficial in terms of skill learning, motivation (Wilson et al., 2009), perceived relevance and perceived self-efficacy (Lakhmani et al., 2012). Experiences of game development and game play in the Gaming Climate Futures project emphasize that finding the right balance between realism and simplicity is crucial and at the same time difficult. In a general sense, it can be argued that the level of realism in serious games is important because of the credibility of the game and the potential influence on real-life decision-making. On the other hand, simplicity is important because of the limited time duration of the game, to ensure that the game is understandable and to make sure players will not get cognitively overloaded. When designing a game for climate negotiators, it is important that characteristics of the game are identical to the actual negotiations as much as possible, that decisions in the game resembles the decision-making process and that models behind the game reflect real-life dynamics climate system, socio-economic and technological drivers and political systems. However, all those elements will be too complex and time consuming to include in a game, which means simplified decision options are required and simplified models need to be developed. Experiences of the Tipping Point Negotiations game revealed that careful selection of this is crucial. Involving stakeholders with different areas of expertise in the game development process and performing numerous game testing sessions, which was done in the Gaming Climate Futures project, has proven a fruitful method of balancing simplicity and reality.

A benefit of serious games compared to traditional learning methods is that cognitive load of players can be managed by gradually increasing the learning material and adapting the speed of the learning process to the learner (Greitzer et al., 2007). Therefore, in order to prevent players from getting cognitively overloaded or bored, this should be incorporated in game design, as well as presenting information in small chunks (Greitzer et al., 2007). Experiences of game play in the current project reveal that although it is important that learning goals are achieved as much as possible, this should not be done at the expense of the overall experience of the game. The Tipping Point Negotiations workshop experiences revealed that it takes time to understand the dynamics and decision options of the game. A serious game that involves a complex governance issue, providing too much information in a short amount of time and rushing through game elements is difficult to avoid. However, in order to advance the learning process, it is important that the overall experience of the game is comfortable and that participants have enough time to absorb the information.

Another important finding in previous research is that there is an optimum in how challenging the goals in the game should be and how much control the players should have in order for the players to stay focused and motivated (Wilson et al., 2009). Rumore et al. (2016) found that this also particularly applies to control over climate change outcomes. The current study acknowledges this, as the Tipping Point Negotiations game highlighted that at least one tipping point has already been passed with catastrophic impacts, further passing of tipping points may be avoided by reducing their likelihood by limiting global warming. This shows that business-as-usual approaches are inappropriate strategies to pursue the 'win condition' of avoiding tipping points, which motivates players to be engaged in the game. With regard to visualizations of climate change that might be used in the design of climate change games, it has been argued that this should be emotionally engaging, but not fear-inducing (O'Neill & Nicholson-Cole, 2009) and that visualizations of local impacts might be more effective than global impacts, because this reduces the perceived distance of climate change (Spence et al., 2012). Experiences of the Tipping Point Negotiations game indicate that not only visualizations might elicit emotional responses to climate tipping points, but imagining future impacts by means of storytelling might be effective in this regard as well. Considering local as opposed to global impacts in the storytelling exercise might have indeed played a crucial role in this, as participants stated that this exercise made the future risks of climate tipping points much more personal.

Importantly, the current study revealed valuable insights in the role of perceptions of climate tipping points in global climate negotiations and associated governance challenges and the role of serious gaming in addressing these challenges. An important finding in the current study was that participants perceived the risks of climate tipping points as serious and argued that tipping points are important to consider because they emphasize the urgency for (early) climate change action. Thus, increased awareness of critical thresholds of the Earth system might indeed increase the sense of urgency of political action, as supposed by various scholars (Biermann, 2012; Galaz, Biermann, Folke, et al., 2012). However, the political implications of this increased sense of urgency in global climate governance and UNFCCC negotiations specifically, remains unclear. As argued in previous research (Galaz, Bierman, Crona et al., 2012; Gardiner, 2009), the notion of tipping points might affect political decision-making in multiple ways; it might motivate as well as undermine political action regarding climate mitigation. Results of the current study suggest that as long as the UNFCCC lacks the understanding of developing appropriate governance responses to climate tipping points, it is doubtful that this sense of urgency alone will motivate political action or result in the institutional changes that were proposed by Galaz et al. (2016). However, suggesting that tipping points will merely create fear and feelings of helplessness that reduce confidence in climate change solutions (Bellamy & Hulme, 2011; O'Neill & Nicholson-Cole, 2009), also seems an unlikely perspective on how the climate negotiation community perceives and responds to climate tipping points. Rather, there seems to be a mismatch between on the one hand high perceived seriousness of the risks associated with climate change and high concern about the issue, and on the other hand a lack of understanding of climate tipping points within the climate negotiation community and a lack of confidence in the UNFCCC regarding governance responses to climate tipping points. Thus, the possible governance responses to climate tipping points as well as governance challenges (e.g. Galaz, Biermann, Crona et al., 2012) should be further explored within global climate negotiations specifically and global climate governance more generally.

Results of the current study also provide insights in the communication of scientific insights on climate tipping points and in particular the role of uncertainty, as study participants argued this may hamper governance responses. This finding is in line with earlier findings that cooperation in climate negotiations might be promoted when uncertainty of the thresholds of climate tipping points is low (Barrett & Dannenberg, 2012; 2014). Reducing scientific uncertainty by means of early warning of climate tipping points might thus indeed be favorable in promoting risk management strategies (Lenton, 2011). However, these propositions require that the UNFCCC community knows how to respond to climate tipping points, which might currently be inadequate (Milkoreit, 2015). Moreover, results of the current study revealed that the approach of communicating uncertainty is a crucial issue, particularly in the case of climate tipping points. Although the level of uncertainty involved in climate tipping points is high and the relationship to global temperature is non-linear and complex, this uncertainty should not hinder the feeling that individuals have a certain level of control over their likelihood. The feeling of having very little control on avoiding climate tipping points might reduce the motivation for cooperation in global climate negotiations. The current research reveals that this might not only have to do with the actual level of uncertainty of the threshold (e.g. Barrett and Dannenberg, 2012; 2014), but also with how this uncertainty is communicated. In the Tipping Point Negotiations game, it was clearly communicated that the likelihood of passing climate tipping points (despite large uncertainty regarding their actual thresholds), increases with global temperature increase and that their decisions influence the likelihood of passing tipping points through this mechanism.

Results of the current study indicate that serious games are promising tools that might be valuable in bridging the identified knowledge – risk perception and risk perception-perceived efficacy gaps associated with climate tipping points. In particular, the current research supports the potential of role-playing simulation games in providing an emotionally engaging learning experience that increases awareness and concern of climate change risks (Rumore, 2015; Rumore et al., 2016). As such, role-playing simulation games might indeed be successful in creating a shared sense of the collective risks posed by climate change, which is an important condition for collective decision-making in response to those risks (Rumore et al., 2016). Thereby, by addressing differences in risk perceptions, which pose governance challenges related to planetary boundaries (Galaz, Biermann, Crona et al., 2012), role-playing simulations might be promising instruments in overcoming some of these challenges. However, it should be taken into account that political decision-making is influenced by many complex interacting factors such as economic interests, power and resources and thus the actual influence of risk and efficacy perceptions should not be overestimated.

The current research also provides some interesting insights in how role-playing simulation games enable players to 'safely experiment' with possible strategies, pathways and policy challenges (Mayer, 2009; Rumore et al., 2016) and how this might change the understanding of governance strategies (e.g. Van der Wal et al., 2016) or affect confidence in collective action (e.g. Mendler-de Suarez et al., 2012). Results of the current study suggest that although exploring potential future impacts of (collective) decisions might create a sense of urgency of political action, this does not necessarily change perceptions regarding the capability of avoiding tipping points or provide an adequate understanding of possible governance responses. Therefore, a better understanding of the possible pathways and governance responses (and challenges) related to climate tipping points will most likely involve a form of serious gaming with scenario development in which the various possible governance options are explored in more detail. Similar to the approach by Kok et al. (2011), this may entail a combination of exploratory scenario development (i.e. focused on raising awareness, promoting creative thinking and providing insights in relationships between driving forces) and backcasting scenario development (i.e. visioning desirable futures, discussing possible challenges and opportunities related to this future and developing strategies towards this desirable future). Therefore, extending the Tipping Point Negotiations game, which mainly involved exploratory scenario elements, with backcasting elements would allow for further exploration of possible governance responses to climate tipping points.

The recommendations regarding how governance challenges associated with climate tipping points could be addressed, in particular challenges related to mismatches in knowledge and perceptions, may be summarized as follows:

- Improving the understanding of climate tipping points within the climate negotiations community is urgently required. In addressing the science-policy gap in international climate negotiations, novel interactive science communication tools need to be developed in which communication of uncertainty plays a crucial role.
- Governance challenges in global climate negotiations related to differences in risk perceptions should be addressed by developing methods that create a shared sense of the collective risks of climate tipping points.
- A better understanding of appropriate governance responses and challenges within the climate negotiations community is urgently required.

Serious games and role-playing simulation games in particular might be promising tools in addressing these issues and their use is this context is therefore recommended, because of the following reasons:

- Serious gaming might be promising as science-policy interface, because this interactive learning method allows for active exploration of complexity, uncertainty and dynamics of climate tipping points.
- Serious games can create an emotionally engaging experience that have the ability to change perceptions of the risks associated with climate tipping points and thereby emphasize the urgency of political action
- Serious gaming allows for the combination of different scenario approaches that not only raises awareness and promotes creative thinking, but also enables players to explore challenges and opportunities of different governance strategies.

7. Conclusion

The present research has provided valuable insights in risk and efficacy perceptions associated with climate tipping points among participants of global climate negotiators and other professionals that are actively involved in climate change and how a role-playing simulation game might influence these perceptions. Crucial differences in perceptions between the various types of risks involved in climate tipping points were revealed as well as underlying factors of perceptions. The risks of climate tipping points were perceived as highly serious and concern of this issue was high. However, there was a lack of confidence about the understanding of the UNFCCC in developing governance responses to climate tipping points (i.e. low perceived efficacy). Thus, the present research points to a mismatch in international climate negotiations between on the one hand high perceived risk and on the other hand a lack of knowledge and perceived efficacy regarding appropriate governance responses. The present research revealed that a role-playing simulation game can influence perceived risk, in particular by providing an emotionally engaging learning experience, bringing the risks closer and making them more personal. However, no changes in perceived efficacy were observed, which can most likely be explained from the inadequacy of the current game in exploring response options. A better understanding of appropriate governance responses will most likely entail a combination of exploratory and backcasting scenario elements, that not only improves understanding, raises awareness and promotes future thinking, but also allows for exploration of possible pathways and associated challenges and opportunities. Serious games are promising tools in this regard, and might therefore useful in addressing the identified mismatch in global climate negotiations. In conclusion, this research highlights the potential of serious gaming as science-policy interface in global climate governance and brings novel insights in the role of cognition in understanding political dynamics.

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Appendix I The Gaming Climate Futures project

The 'Gaming Climate Futures' project is a collaborative international research effort between four universities; Purdue University, Glasgow Caledonian University, the University of Exeter and Utrecht University. The project was initiated and coordinated by Manjana Milkoreit, Assistant Professor of Political Science at Purdue University and is aimed at engaging global climate negotiators to explore the relationship between climate tipping points and global temperature goals, in light of the Paris Agreement. The ultimate goal of the project is to engage global policymakers: to inform political interests and negotiation goals of participants of the UNFCCC negotiations regarding global temperature goals.

The project is a 'knowledge co-production process' between scientists and policymakers on urgent challenges in global climate governance. The project addresses the current science-policy disconnect in climate change politics by developing a technology-supported serious game and studying its effectiveness in terms of cognitive changes (knowledge and beliefs) and long-term political dynamics in global climate negotiations. The main goals of the role-playing simulation game are to:

- deepen the understanding among political actors on decision-making on pursuing global temperature goals and its relationship with passing particular climate tipping points
- enable political actors to imagine possible economic-technological, socio-political and environmental futures that their collective decision-making could create

The project consists of four phases with a time frame of 2.5 years (January 2017- June 2019). I was involved in part of Phase 3 (Scenario and Game Design) and the entire Phase 4 (Game workshops in Bonn) of the project.

Appendix II Game development process

Prior to the game development process (during Phase 1 and Phase 2), current knowledge needs, beliefs and political interests of the climate negotiation community regarding global temperature goals and climate tipping points were explored. This informed the first steps in developing the role-playing simulation game that addresses current knowledge needs of participants of global climate negotiators around these issues. In Phase 3 of the project, first the learning goals, the role of uncertainty and the design of the game were determined. Also the tipping elements that would be included in the game were carefully selected based on multiple characteristics based on available scientific evidence, ability to avoid the tipping points, regional vs. global impacts, temporal dimension of the impacts and the types of impacts (different impacts on human wellbeing and terrestrial vs. marine effects on ecosystems) in order to ensure a diverse set of tipping elements was included. The final selection were the following: Coral Reef Dieback, West-Antarctic Ice Sheet (WAIS), Arctic Summer Sea Ice (ASSI), the Indian Summer Monsoon and Boreal Forests Dieback. This was all prior to my involvement in the project. The game development was a collaborative effort of the whole project team consisting of researchers with varying areas of expertise including political science, climate science and game design (including myself, from November 2017 on). The game interface for Part 1 of the game was designed by game design students of Glasgow Caledonian University, coordinated by a game design lecturer of that university. Iterative testing with different versions of the game followed with undergraduate students at Glasgow Caledonian University, Purdue University and Utrecht University. Based on experiences of participants of the game testing and observations by the researchers during the game testing sessions, the game was adjusted in terms of duration and difficulty. The additional game materials for Part 1 and 2 of the game, including country profiles, event cards and game instructions, were developed by multiple project team members.

Appendix III Personal involvement in the project

My involvement in the Gaming Climate Futures project started in November 2017 and consisted of the following elements:

A. Game development

- General support in game development:
  Providing insights in how the game could be potentially improved, focusing particularly on insights from applied cognitive psychology and contribute to discussions on game development in team meetings.

- Developing Plan B of the Tipping Point Negotiations game
  It was not clear if a complete version of the Tipping Point Negotiations game would be finished in time. Guided by Joost Vervoort and Manjana Milkoreit, it was my task to develop a Plan B version of the game that would be used if the original version would not be finished in time. Because of a lack of time and experience with game design, this game consisted of a paper-based version of the original game, supported by an existing climate simulation model. On the day of the first workshop in Bonn, the original game worked for the first time without any bugs and it was decided that Plan B was not used for the workshops. The process of developing this Plan B was as follows:

  - Identifying a climate simulation model:
    C-ROADS was identified as appropriate climate simulation model because of its simplicity, ease in use, scientifically sound (developed by a team of researchers of MIT and reviewed by a committee of the IPCC) and widely used. C-ROADS is a free climate simulation model developed by MIT Climate Interactive and used in combination with World Climate Simulation; a role-playing negotiation game that resembles UNFCCC negotiations that is used worldwide in various settings; businesses, organizations, higher education, etc. Inputs of this model are emission reduction pledges by global region. Different outputs can be chosen including global greenhouse gas emission global temperature increase.

- Develop model to translate inputs of original game to inputs for C-ROADS
  C-ROADS differed from the original game in two important ways; (1) the countries/regions of inputs and (2) the type the input values. First, C-ROADS uses input values of the following global regions: US, EU, China, India, Other Developed, Other Developing. Except of the first four, the 30 countries included in the original game were all part of either 'Other Developed' or 'Other Developing' regions. Because the game needed to closely follow the logic of the UNFCCC (based on individual countries and alliances), I created a model that combines inputs of different countries of the original countries into inputs for the regions as defined in C-ROADS. Secondly, the inputs of C-ROADS are based on emissions whereas in the original game decisions of players are national budget allocations. In the original game, a model was included in the game interface that automatically translates these budget allocations into global emissions and temperature and calculates contributions to collaborative funds. For Plan B I created a similar model in an Excel sheet for each of the 30 countries in which players were able to put their budget allocations, with a formula that translates budget allocations into percentage annual emission reductions (with fixed amount of \$/tonCO_2 and based on current emissions of each country), which was used as input for C-ROADS. Another formula in Excel added all contributions of the ICF and NET. This online Excel sheet was used as proxy for the game interface of the original game.

- Developing a system for passing of climate tipping points.
  The same climate tipping points that were included in the original game were also included in the Plan B version. Because the original had a built-in system that determines whether tipping points are passed, a similar system needed to be created. Manjana Milkoreit provided this system: based on the probability functions of each of the tipping points (with on the X-axis global temperature increase and Y-axis probability of passing the tipping point), two 1-10 dice were rolled to create a number between 1 and 100. If the number that was rolled was within the probability range of the tipping point, the tipping point was crossed and if outside this range, the tipping point was not crossed. A dice rolling website was used for this.

- Adjusting number of negotiation rounds
  The original game consists of 5 negotiation rounds starting in 2018 and ending in 2043. In C-ROADS it is only possible to choose the beginning year and the program calculates emissions and temperature until the year 2100. Therefore, an iterative process is only possible if manually adjusting for each negotiation round and it was therefore decided to only do one negotiation round, but to play this round two times, which allows players to learn and adjust their strategies based on experiences of the first round of play.

- Developing additional game materials

  Because of the country translations, the country profiles that were created for the original game could be used for the Plan B version of the game as well. However, new game instruction materials were created as well as information on probabilities of climate tipping points and global temperature by Manjana Milkoreit and me.

- Game testing

  A preliminary version of the Plan B version of Part 1 of the game and Part 2 of the game were tested by me and Joost Vervoort in a game testing session at Utrecht University with 19 undergraduate Environmental Sciences students. I was responsible for organizing the testing, including recruitment of participants, organizing the room, food and drinks, creating surveys to gain insights in participants' experiences and creating slides to facilitate the game testing. The game testing was performed by Joost Vervoort and me; introducing climate tipping points, explaining instructions, facilitating the negotiation process, helping with problems and observing, taking notes about participants' experiences and a debriefing session in which participants' shared their experiences. This game testing session provided key insights that informed development of the final version of Plan B of the game.

- Developing game materials:
  - Country profiles and alliance information:

    I developed 5 out of 30 country profiles; collecting data from different online data sources about all country profile elements (see 'Game characteristics'), formatting pages and adjusting this according to feedback. In addition, I helped with the creation of information about negotiation stance and history of the different negotiation alliances included in the game.

  - Transition narratives

    In order to 'transition' from the end of the Part 1 (negotiations) to Part 2 (storytelling), I developed 8 narratives based on the outcomes of the negotiations about global changes from 2043 to 2118; each narrative corresponding to one RCP emission / global temperature scenario as defined by the IPCC (2014) and one or two Shared Socio-Economic Pathway scenarios (O'Neill et al., 2014). Based on the outcomes of Part 1 of the game in terms of global temperature and passing of climate tipping points one of the narratives could be chosen. The narratives entailed general global developments such as global temperature, GHG concentrations, sea level rise and ocean acidification as well as regional development for each continent and description of impacts of specific climate tipping points.

B. Research

- <u>Contribution to survey instrument</u>

  I was responsible for developing risk perception and perceived efficacy items of the survey instrument that were based on measurements of these construct in previous research.

- <u>Online survey climate change professionals</u>

  I conducted an online survey among professionals that are actively working in the field of climate change. This consisted of the following elements:

  - Applying for approval of Ethics Committee Beta-Geo (this was required to fulfill requirements by the Institutional Review Board of Purdue University, in to confirm that research activities performed by me and Joost Vervoort and me were approved according to ethical standards of Utrecht University and to confirm that Utrecht University carries responsibility for research performed at our institution). Approval was granted.
  - Identifying networks of professionals (supported by Joost Vervoort and Charlotte Ballard)
  - Developing recruitment emails and contacting networks
  - Discussing content of survey instrument with project leader: in order to promote a high response rate, the survey duration was set at 15 minutes, meaning that the survey instrument that was used in the pre-workshop surveys was shortened. In collaboration with Manjana Milkoreit, it was ensured that the data was useful for my research (therefore containing all risk perception and perceived efficacy items) as well as additional research performed by the research team (i.e. particularly knowledge of climate tipping points)
  - Creating survey in Qualtrics
  - Perform pilots with survey (with fellow students of Sustainable Development)
  - Data entry (Excel, SPSS and NVivo)
  - Data analysis (SPSS and NVivo)

- <u>Contribution to workshops in Bonn</u>

  - Participant recruitment:

    Five project team members including me identified participants for the workshops in Bonn: NGO representatives that participated in previous UNFCCC meetings. This included finding contact information and creating invitation documents. The identification of participants and recruitment was coordinated by Manjana Milkoreit.

  - Preparing, supporting facilitation and observing during workshops

    A large share of the project team, including me, attended the workshop sessions in Bonn. I contributed to preparation of the workshops, evaluation and discussions on adjustments. The main facilitators of the workshops were Manjana Milkoreit and Joost Vervoort. The remaining project team members, including me, supported the facilitation and observing and taking notes of participants' statements and interactions. The notes of all four observers were collected in a shared document directly after the workshops.

Additional supporting tasks

- Attending team meetings and providing input
- Contribution to literature reviews: creating bullet point versions of my literature reviews and practical insights for game design and shared this with the project teams for later use.
- Expert brochure: developing a brochure for workshop participants about the project and expertise of all project team members that participants can use to contact for more information about the project and about (policy-relevant) information about climate tipping points. This entailed:
- Thank you card Glasgow students. Developing a thank you card for the game design students with pictures of the workshops and quotes from participants.

Appendix IV Survey Instruments

Pre-workshop and online survey instrument

** = not included in online survey*

Global Temperature Goals

Q2.1 What is the most appropriate global temperature goal from your personal perspective? [1.5ºC – well below 2ºC - 2ºC – more than 2ºC]

Q2.2 Please briefly explain your reasoning

Q2.3 What is required to meet a 1.5ºC temperature goal according to your best understanding of the currently available science? [… % emission reductions – below …. Levels – by year …. – other requirements]

Q2.3 What is required to meet a 2ºC temperature goal according to your best understanding of the currently available science? [… % emission reductions – below …. Levels – by year …. – other requirements]

Climate Tipping Points

Q3.1 Do you know a definition for the phrase "climate tipping point"? [yes / no]

Q3.2 If you answered “Yes “in Q3.1, how do you define climate tipping points?

Q3.3 In its 5th Assessment Report, the IPCC defines a climate tipping point as "A level of change in system properties beyond which a system reorganizes, often abruptly, and does not return to the initial state even if the drivers of the change are abated" (IPCC 2014).

Q3.4 Please select all of the following that represent climate tipping points: [Disintegration of the West Antarctic Ice Sheet – sea level rise – reaching an emission peak - dieback of the Amazon rainforest – success of the global stocktake - an increase in the number ant intensity of hurricanes / cyclones – permafrost melt / tundra methane release – ratification of the Paris Agreement – El Nino / La Nina.

Q3.5 How concerned are you about climate tipping points? [not concerned – somewhat concerned – concerned – rather concerned – extremely concerned]

Q3.6 If we were to pass the following climate tipping points today, how long would it take to experience significant impacts? (Coral Reef Dieback, Boreal Forest Shift/Dieback, West Antarctic Ice Sheet Collapse, Arctic Summer Sea Ice Loss: immediately/after a few years – after a few decades – after a century)

Q3.7 Are climate tipping points important for global policy-makers? [yes/no]

Q3.8 Please briefly explain your answer to Q3.7.

Risk & Climate Tipping Points

Q4.1 How likely do you think it is that we have already passed one of the following two tipping points on an uncertainty scale from <1% (exceptionally unlikely) to >99% (virtually certain)? (Coral Reef Dieback, Arctic Summer Sea Ice Melt).

Q4.2 How serious of a risk do you think climate tipping points are in general / there is of one or more climate tipping points having a significant negative impact on your country / there is of one or more climate tipping points having a significant negative impact on other countries? (not serious – somewhat serious – serious – rather serious – extremely serious)

Q4.3 Please indicate the level of risk you believe climate tipping points pose to the following factors for humanity in general: Food and water security, security (i.e. violence, conflict, war), prosperity (i.e. income, wealth, property) (not serious – somewhat serious – serious – rather serious – extremely serious

Q4.4 Please indicate the level of risk you believe climate tipping points pose to the following factors in your life. My food and water security, my security (i.e. violence, conflict, war), my prosperity (i.e. income, wealth, property) (not serious – somewhat serious – serious – rather serious – extremely serious

Agency

Q5.1 Please indicate your level of agreement or disagreement with the following statements. [strongly disagree-somewhat disagree-neither agree nor disagree – somewhat agree – strongly agree]

- By acting collectively, countries are capable of influencing the likelihood of avoiding or triggering climate tipping points.
- My personal actions in my capacity as a UNFCCC delegate can influence the likelihood of avoiding or triggering climate tipping points.
- The climate negotiation community knows what should be done to respond effectively to climate tipping points.
- The collective ability of the climate negotiation community to respond effectively to climate tipping points heavily depends on the willingness of a small number of important actors to support global cooperative solutions.
- My country is part of that small group of important actors.
- My country is able to influence the decision-making of actors in that important group.

Q5.2 Please add any additional comments you may have about the above statements.

Knowledge & the Future

*Q6.1 Please indicate your level of agreement or disagreement with the following statements. [strongly disagree-somewhat disagree-neither agree nor disagree – somewhat agree – strongly agree]

- I believe the long-term effects of climate change (i.e. those occurring 50 or more years into the future) are very important for the decisions we make in the UNFCCC today.
- I struggle to imagine the long-term effects of climate change (i.e., those occurring 50 or more years into the future)
- Some topics in climate science are difficult for me to understand.
- I know as much about climate science as I need to
- Climate science informs my strategic thinking / policymaking.
- I am interested in learning more about climate tipping points.
- It is easier for me to learn about climate change through interactive experiences (e.g. games, webinars, hands-on activities, etc.) than by reading.

*Q6.2 When you think about the future in the context of climate change, what time frame do you have in mind?

*Q6.3 What are the first three words that come to mind when you think about the near future (5-10 years from now) in the context of climate change?

*Q6.4 What are the first three words that come to mind when you think about the distant future (50 or more years from now) in the context of climate change?

Expectations

*Q7.1 What do you hope to gain from the Tipping Point Negotiations workshop? Please select all that apply. (Enhanced knowledge of climate tipping points – enhanced knowledge of global temperature goals – enhanced ability to envision world futures – personal engagement with other diplomats or players outside the negotiation space, other please explain)

Demographics

Q8.1 What is your role at the negotiations? (Diplomat/member of a party delegation - representative of a civil society organization (NGO) – representative of the private sector or business community – scientist (IPCC or observer) – member of the UNFCCC Secretariat – Representative of an intergovernmental organization- other)

Q8.2 What is your nationality?

Q8.3 What is your gender? ____

Q8.4 What is your age?____

Q8.5 How many UNFCCC COPs (not SB sessions) have you attended? ________

*Q8.6 What is your current area of expertise and responsibility related to the climate negotiations (e.g., mitigation, Loss & Damage, gender & climate

Appendix V Quantitative results

A. Descriptive statistics risk perception items

	Statistics	
Risk perception item	M	SD
Concern	4.21	.978
RP.General	4.15	.855
RP.OwnCountry	3.75	1.176
RP.OtherCountries	4.51	.748
SRP.Food&Water	4.39	.897
SRP.Security	4.01	.957
SRP.Prosperity	4.04	1.013
PRP.Food&Water	2.68	1.287
PRP.Security	2.51	1.289
PRP.Prosperity	2.72	1.197

B. Descriptive statistics perceived efficacy

	Statistics	
Perceived efficacy item	M	SD
CollectiveEfficacy	4.37	.879
PersonalEfficacy	3.13	1.100
NegotiationCommunity	2.99	1.264
ImportantActors	3.83	1.001
CountryDirectInfluence	3.39	1.299
CountryIndirectInfluence	3.44	1.296

C. Socio-demographic influences of risk perception

Socio-demographic factor	Risk perception variable	Statistic M	Statistic SE_{diff}	Sig. (2-tailed)
Gender	Risk Perception Index	-.070	.180	.684
	Societal Risk Perception	-.183	.204	.372
	Personal Risk Perception	-.303	.284	.290
		Spearman's rank correlation		
Age	Risk Perception Index	-.060		.642
	Societal Risk Perception	-.179		.150
	Personal Risk Perception	.150		.234

*p<0.05

D. Differences in risk perception between different types of organizations

Variable		df	SS	MS	F	p
Risk Perception Index	Between Groups	4	2.23	.56	1.169	.339
	Within Groups	40	19.07	.48		
	Total	44	21.3			
Societal Risk Perception	Between Groups	4	4.31	1.08	1.694	.170
	Within Groups	40	25.4	.64		
	Total	44	29.7			
Personal Risk Perception	Between Groups	4	1.60	.40	.425	.789
	Within Groups	40	37.51	.94		
	Total	44	39.10			

E. Correlations between perceived efficacy items (N=68)

Perceived efficacy item	1	2	3	4	5	6
1. CollectiveEfficacy	---					
2. PersonalEfficacy	.445**	---				
3. NegotiationCommunity	.055	.106	---			
4. ImportantActors	-.085	-.117	.365**	---		
5. CountryDirectInfluence	.101	.277*	.272*	.405**	---	
6. CountryIndirectInfluence	.144	.257*	.202	.295*	.697**	---

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

F. Difference between personal and collective efficacy

Variables	Difference M	Difference SD	95% CI for Mean Difference	r	t	df
Collective efficacy, personal efficacy	1.239	1.088	.973, 9.317	.415	9.317*	66

*p<0.05

G. Socio-demographic influences of perceived efficacy

Socio-demographic factor	Perceived efficacy item	Statistic M	Statistic SE_{diff}	Sig. (2-tailed)
Gender	CollectiveEfficacy	.008	.230	.971
	PersonalEfficacy	-.320	.286	.268
	NegotiationCommunity	-.226	.328	.493
	ImportantActors	-.190	.266	.477
	CountryDirectInfluence	-.196	.341	.569
	CountryIndirectInfluence	-.002	.350	.995
		Spearman's correlation		
Age	CollectiveEfficacy	-.035		.787
	PersonalEfficacy	-.055		.669
	NegotiationCommunity	-.087		.499
	ImportantActors	-.036		.779
	CountryDirectInfluence	-.187		.145
	CountryIndirectInfluence	-.212		.104

*p<0.05

H. Correlations risk perception and perceived efficacy

	Collective Efficacy	Personal Efficacy
Risk Perception Index	.266*	.349**
Societal Risk Perception	.045	.142
Personal Risk Perception	.234	.348**
Concern	.274*	.241
RP.General	.027	.272*
RP.OwnCountry	.117	.156
RP.OtherCountries	.165	.130
SRP.Food&Water	.119	.072
SRP.Security	-.085	.034
SRP.Prosperity	.135	.146
PRP.Food&Water	.206	.382**
PRP.Security	.097	.304*
PRP.Prosperity	.224	.246*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Workshop participants (N=25)

	Collective Efficacy	Personal Efficacy
Risk Perception Index	.242	.243
Societal Risk Perception	-.162	-.171
Personal Risk Perception	.185	.292

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Online survey participants (N=42)

	Collective Efficacy	Personal Efficacy
Risk Perception Index	.224	.301
Societal Risk Perception	.156	.183
Personal Risk Perception	.217	.284

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Climate negotiators (N=39)

	Collective Efficacy	Personal Efficacy
Risk Perception Index	.178	.371*
Societal Risk Perception	-.117	.177
Personal Risk Perception	.166	.324*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Non-negotiators (N=28)

	Collective Efficacy	Personal Efficacy
Risk Perception Index	.234	.280
Societal Risk Perception	.209	.091
Personal Risk Perception	.050	.308

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

I. Correlations risk perception and temperature goal preference

Risk perception variable	Temperature goal preference
Risk Perception Index	-.283*
Societal Risk Perception	-.305**
Personal Risk Perception	-.237*
Concern	-.157
RP.General	-.155
RP.OwnCountry	-.157
RP.OtherCountries	-.097
SRP.Food&Water	-.376**
SRP.Security	-.251*
SRP.Prosperity	-.224
PRP.Food&Water	-.112
PRP.Security	-.158
PRP.Prosperity	-.300*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

J. Correlations perceived efficacy and temperature goal preference

	Temperature goal preference
CollectiveEfficacy	-.046
PersonalEfficacy	.016
NegotiationCommunity	-.113
ImportantActors	-.224
CountryImportantActors	.099
CountryIndirectInfluence	-.082

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

K. Changes in risk perception after workshop

Comparison	Difference M	Difference SD	95% CI for Mean Difference	r	t	df
Risk Perception Index	.250	.180	-.176, .676	.782	1.387	7
Societal Risk Perception	.593	.253	.009, 1.177	.859	2.340*	8
Personal Risk Perception	.037	.263	-.570, .644	.788	.141	8
Concern	.222	.667	-.290, .735	.803	1.000	8
RP.General	-.200	.919	-.857, .457	.291	-.688	9
RP.OwnCountry	.500	1.269	-.408, 1.408	.293	1.246	9
RP.OtherCountries	.100	.568	-.306, .506	.818	.557	9
SRP.Food&Water	.444	.882	-.233, 1.122	.764	1.512	8
SRP.Security	.444	1.130	-.424, 1.313	.703	1.180	8
SRP.Prosperity	.889	.601	.427, 1.351	.892	4.438*	8
PRP.Food&Water	.222	.441	-.117, .561	.940	1.512	8
PRP.Security	-.333	1.225	-1.275, .608	.607	-.816	8
PRP.Prosperity	.222	.972	-.525, .969	.672	.686	8

*p<0.05

L. Changes in perceived efficacy after workshop

Comparison	Difference M	Difference SD	95% CI for Mean Difference	r	t	df
CollectiveEfficacy	-.222	.441	-.561, .117	.500	-1.512	8
PersonalEfficacy	-.250	1.035	-1.115, .615	-.112	-.683	7
NegotiationCommunity	.333	.707	-.210, .877	.831	1.414	8
ImportantActors	.000	1.118	.859, .859	.375	.000	8
CountryDirectInfluence	.111	1.616	-.131, 1.353	-.110	.206	8
CountryIndirectInfluence	.000	.756	-.632, .632	.484	.000	7

Appendix VI Qualitative analysis and results

A. Codebook for catagorizing importance question

Importance	Description and criteria	N
Yes	Participants that indicated that climate tipping points are important to take into account for policy-makers, as indicated explicitly by answering 'yes' to the question: "Are climate tipping points important for policy-makers?" or implicitly by providing reasons why climate tipping points are/should be important to consider by policymakers or that policymakers are/should be concerned about tipping points.	52
No	Participants that indicated that climate tipping points are currently not (seen as) important to take into account by policy-makers or are not concerned about climate tipping points.	6
Yes/no	Participants that provide reasons for importance of climate tipping points for policymakers as well as reasons why they are not important and participants that indicate that the answer to this question depends on other factors.	7
Should be important but currently not*	Participants that explicitly stated that climate tipping points should be important issues to take into consideration or should be concerned about tipping points, although they are currently not considered important by policymakers or policymakers are currently not concerned about them.	5

*this category has some overlap with the categories 'yes' and 'no'.

B. Codebook analyzing underlying reasons 'important'

* = predefined category based on theory.

Argument category	Argument	Criteria	Example statements	N
Emphasize urgency of early action	Climate tipping points are important because they emphasize the urgency of early climate change action	Statements that specifically indicate "urgency" in relation to "climate change action", or statements about the consequences if action is absent or too late (e.g. "policy inaction", "consequences of inaction"), or statements that indicate urgency of policy action (e.g. "policy now")	"they inform the urgency of addressing climate change" "they emphasize the urgency of action" "climate tipping points puts greater emphasis, need and potential benefit on acting on climate change today"	9
Guiding policymakers	Climate tipping points guide policymakers in	Statements about policymaking and decision-making in relation to climate	"policymakers need to be concerned in order to make	12

	decision-making on climate change, such as formulating policy goals.	tipping points (e.g. "decision making", "policymaking", "guides", "creating policies")	decisions" 'the existence of tipping points which are irreversible can be important guides for climate policymaking"	
Seriousness of impacts*	Climate tipping points are important because of their catastrophic and irreversible impacts and structural changes in system dynamics	Descriptions of the (severity and irreversibility) impacts on climate tipping points on human wellbeing and ecosystems (e.g. "large impacts", "irreversible changes", "large influence")	"they will have major impacts on society and human wellbeing" "important because the system changes rapidly and irreversibly" "some would be catastrophic for earth's system"	28
Moral argument	It is our moral obligation that climate tipping points are prevented	Moral considerations about tipping points (e.g. "moral standard", "ethical")	"without global efforts, there will be lack of global pressure and ethical/moral standard to be followed"	2
Relationship with global temperature	Climate tipping points are important to consider because the likelihood increases with increasing global temperature.	Statements about global temperature in relation to tipping points (e.g. "increase in global temperature", "degrees Celcius").	"higher future average global temperatures are associated with a higher chance of tipping points occurrence."	3
Likelihood / uncertainty*	Uncertainty in thresholds and the climate system.	Statements about the unpredictability of thresholds and uncertainty in the climate system (e.g. "uncertainty of the climate system", "difficult to predict")	"they are hard to know when they will happen because of feedbacks and delays" "they are standing for complexity and uncertainty of climate systems"	6

C. Codebook for analyzing underlying reasons 'not important'

* = predefined category based on theory.

Reason	Description	Criteria	Example statements	N
Temporal distance*	The threats of climate tipping points are perceived as temporally distant and abstract.	Statements indicating that climate tipping points are abstract, indirect or distant (e.g. "abstract", "indirect", distant", "timeframe")	Statements about timing of climate tipping points in relation to political terms (e.g. "political term", "term of office", "timeframes") "Not sure that the policy-makers are interested in tipping points, except if we can proof that they will happen within their term of office"	9

Lack of knowledge	Policymakers lack knowledge about climate tipping points	Statements about insufficient knowledge levels of policy-makers (e.g. “lack of knowledge”, “don’t know”)	“they are not highly important to policymakers, due to lack of knowledge”	**3**
Competing political issues	Other political issues compete with climate tipping points in the political arena.	Statements about relative importance of climate tipping points compared to other issues.	“not as important as other issues at the moment.” “they tend to have so many problems”	**2**
Confidence in adaptation	Confidence in adapting to impacts of climate tipping points makes avoiding them less important.	Statements about confidence in climate change adaptation in relation to climate tipping points	“unfortunately many assume that it is possible to adapt”	1
Negative impacts science-policy dialogue	Insights in climate tipping points might have negative impacts for the science-policy dialogue	Statements about negative impacts of climate tipping points in the science-policy dialogue	“implying that we know at what temperature or when a specific tipping element will occur may hurt the science-policy dialogue in the long run”	1

D. Sub categories of reasoning underlying importance of climate tipping points

Importance	Underlying reason	Sub category	Example statements	N
Important	Emphasize urgency of early action	Tipping points show the consequences of inaction	“the major reason for their importance for policymakers is to set an example of what policy inaction could lead to”	3
		Tipping points emphasize that later action is less effective or more costly	“Once reached, policy will have little to no effect for potentially hundreds or thousands of years” “the future costs of not acting could potentially be catastrophically high”	4
	Guiding policymakers	Guidance in formulating policy goals and strategies	“they are important benchmarks to consider when formulating goals and strategies to attain those goals”	7
		Guidance in domestic policymaking	“to make their countries and economies more resilient, protect their people”	1
	Impacts	Agriculture	“affecting agriculture irreversibly”	1
		Human wellbeing	“they will have major impacts on society and human wellbeing”	4
		Socio-economic impacts (i.e. peace, economy, poverty, access to food and water)	“about poverty and war” “impact heavily on economics” “human rights to clean water and food”	7
		System dynamics / structural system changes	“exceeding these tipping points will have structural implications on the long run” “important because the system changes rapidly and irreversibly”	9

E. Codebook for analyzing underlying reasons ‘not important’

Category	Reasons	Statements	N
Collective efficacy	Issues of level playing fields	“issues of level playing fields globally reduce the likelihood of collective action”	1
	Uncertainty in climate system hampering governance responses	“There is still uncertainty surrounding how ecosystems will react, which can make it difficult to know what to do” “Difficult to respond as the climate science behind triggers / thresholds are not fully defined / understood”	2

Efficacy UNFCCC	Conflict short-term (economic) and long-term (sustainability) interests	"within the framework of global capitalism, the means of the climate community to effectively mitigate greenhouse gases are limited, due to the often times inherent conflict of short-term economic interests and long-term sustainability"	1
Efficacy at country level	Lack of power to influence global policy	"The Netherlands are a small country, at the sea. We will see a direct effect of passing tipping points, but don't have enough power to change the worldscourse. In saying that, we should do more to inspire other countries."	1
	Politicization of climate issues	"states are acting, but not rapidly enough and the politicization of climate issues will continue to slow effective policy until we are past tipping points."	1

F. Codebook for categorizing types of perceived efficacy

Category	Description/criteria	Example statements	N
Collective efficacy	Statements about collective efficacy or collective action (e.g. "collective action")	"issues of level playing fields globally reduce the likelihood of collective action"	2
Efficacy UNFCCC	Statements about efficacy of the UNFCCC negotiation community (e.g. "UNFCCC", "climate community")	"within the framework of global capitalism, the means of the climate community to effectively mitigate greenhouse gases are limited, due to the often times inherent conflict of short-term economic interests and long-term sustainability"	2
Efficacy at country level	Statements about efficacy of individual countries in taking action themselves, achieving collective goals or influencing other countries.	"The Netherlands are a small country, at the sea. We will see a direct effect of passing tipping points, but don't have enough power to change the worldscourse. In saying that, we should do more to inspire other countries." "United States need to part of negotiations and lead the world, - without its presence it will be tough to achieve the goals"	5
Governance response to climate tipping points	Statements about actions (governance responses) in general in addressing climate tipping points (e.g. strategies that could be taken, difficulties that hamper action)	"There is still uncertainty surrounding how ecosystems will react, which can make it difficult to know what to do" "The solutions exist now. They are the best way to invest private and public capital now and in the future"	4

G. Codebook for analyzing underlying reasons of lack of perceived efficacy

Category	Reasons	Statements	N
Collective efficacy	Issues of level playing fields	"issues of level playing fields globally reduce the likelihood of collective action"	1
	Uncertainty in climate system hampering governance responses	"There is still uncertainty surrounding how ecosystems will react, which can make it difficult to know what to do" "Difficult to respond as the climate science behind triggers / thresholds are not fully defined / understood"	2
Efficacy UNFCCC	Conflict short-term (economic) and long-term (sustainability) interests	"within the framework of global capitalism, the means of the climate community to effectively mitigate greenhouse gases are limited, due to the often times inherent conflict of short-term economic interests and long-term sustainability"	1
Efficacy at country level	Lack of power to influence global policy	"The Netherlands are a small country, at the sea. We will see a direct effect of passing tipping points, but don't have enough power to change the worldscourse. In saying that, we should do more to inspire other countries."	1

	Politicization of climate issues	"states are acting, but not rapidly enough and the politicization of climate issues will continue to slow effective policy until we are past tipping points."	1

H. Codebook for analyzing effects of Tipping Point Negotiations game on risk perception

Type of learning experience	Description/criteria	Example statements	Source	N
Climate tipping points were more tangible or concrete	Statements that the game made (risks of/impacts of) climate tipping points more tangible or more 'real' (e.g. "tangible", "more real", "less abstract", "concrete")	"This game is about humanity – you're motivated to be more ambitious when the human dimension is concrete and you feel a connection" "I had a much more tangible sense of tipping points and what it meant to be negotiating or living while they happen"	Survey	2
			Debriefing	5
Personal risks of climate tipping points	Statements that participants learned about the personal risks of climate tipping points (e.g. "personal", "family")	"As an individual it made me think about how they will impact me, my family, my town" "approaching it more personal makes it more touching and motivates to go in a more ambitious way"	Debriefing	2
Type of risks of climate tipping points	Statement about how the game changed beliefs about the types of risks associated with climate tipping points.	"Decision-makers that need to make action need to be much more aware of what tipping points do with water, food and environment. They are all on severe threat. This is not felt as deeply by some negotiators"	Debriefing	1
Uncertainty of risks of climate tipping points	Statements about how the game changed the uncertainty of passing climate tipping points.	"About how uncertain climate tipping points are. What is scary is what we don't know"	Debriefing	1

I. Summary of observational notes of debriefing session: risk perception/concern

	Observer			
Workshop session	*Observer 1*	*Observer 2*	*Observer 3*	*Observer 4*
Session 1	More worried - everyone	More worried	More worried	More worried
Session 2	---	Much more concerned (3), 1 about the same	Much more concerned	Much more concerned
Session 3	More concerned	---	Most participants more concerned, one already concerned	More concerned

J. Summary of observational notes of debriefing session: perceived efficacy/agency

	Observer			
Workshop session	*Observer 1*	*Observer 2*	*Observer 3*	*Observer 4*
Session 1	Less / no change, though they knew what can be done	Less agency	---	Less / no change but know better what can be done
Session 2	---	Decisions need to be more aware, "Game solidified that we only have 1 shot to get it right."	Decisions need to be more aware, "Game solidified that we only have 1 shot to get it right."	Not what to do has changed, but decision-makers need to be more aware.
Session 3	Efficacy regarding specific country	---	Efficacy regarding specific country	Efficacy regarding specific country