# UNIVERSITÀ DEGLI STUDI DI PADOVA

**Dipartimento di Psicologia Generale**
**Dipartimento di Psicologia dello Sviluppo e della Socializzazione**

**Corso di Laurea Magistrale in Psicologi Cognitiva Applicata**

**Tesi di Laurea Magistrale**

# Same trend, different risk perception: how climate change and COVID-19 are differently perceived in relation to their trend.

## Uguale andamento, diversa percezione del rischio: come il cambiamento climatico e il COVID-19 sono percepiti diversamente in relazione al loro andamento.


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Anno Accademico 2021 – 2022

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## 1. Abstract

In our everyday world, we face different kinds and levels of risk, but in the last two years, we have faced an unknown global risk for our health: the SARS-CoV-2 pandemic. Due to this virus, people had to collaborate to limit the spreading of the virus, and it was asking them to change their habits and their lives quite radically. What is relatively interesting from the cognitive point of view is, why and how people perceive this global risk so highly impacting compared to the worldwide issue of climate change?

Both of them follow exponential growth, and from the literature, we already know that people tend to linearize exponential growths when they have to assess them intuitively (Jones 1979; Wagenaar & Sagaria 1975; Wagenaar & Timmers 1979).

Moreover, the SARS-CoV-2 pandemic and climate change are two global issues that afflict the populations differently at all latitudes. In this specific context, the main difference is that climate change is an already known issue compared to the SARS-CoV-2 pandemic, so why did people not react and mobilize the same amount of goods and services to face climate change as they are doing for the spreading pandemic? Why do people perceive these two risks differently?

To answer these questions, we designed a study to investigate the risk perception related to the exponential growth and the effects of this relationship on behaviors in relation to climate change.

## 2. Introduction.

### 2.1 Definition of risk.

The etymology of the "risk" concept has never been unique. Some scholars suggest that the word "risk" origins from the post-classical Latin *resicum, risicum*, etc., meaning "danger, hazard," originated from the classical Latin *resecare,* so "that which cuts" and hence rock and crag, with an illusion to the hazards of traveling by sea. On the contrary, other scholars suggest that *resicum, risicum*, etc. finds its origin from the Arabic word *rizq,* whose meaning was "fortune, luck, destiny, chance" (Althaus, 2005; Aven, 2012; Oxford English Dictionary, 2011). From this explanation of the etymology of the word "risk," what is relevant is the variety of connotations of this word, e.g., if we consider the Latin etymology, the word "risk" has a negative connotation, but positive when we consider the Arabian origins of the word.

Nowadays, the partition of the etymology of the concept "risk" has been maintained for its definition and daily use. As a matter of fact, in daily use, the interlocutors of a speech could refer to a "risk" as a chance or situation involving the possibility of loss, damage, injury, or other adverse or unwelcome circumstances of a hazardous journey, undertaking, or course of action; a venture. A person or thing is regarded as likely to produce a good or bad outcome in particular respect; a person or thing is considered to be a threat or source of danger (Aven, 2012; Slovic & Weber, 2013).

In the literature, there are different definitions of the concept of "risk" and the two that encompass the meanings that the word "risk" could have been the following:

> Risk is a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain (Aven & Renn, 2009; Aven et., 2011; Rosa, 1998, 2003).

> Risk is an uncertain consequence of an event or activity with respect to something that humans value (Aven & Renn, 2009; Aven et al., 2011; Renn, 2009).

Due to the multiplicity of definitions of "risk," some scholars created a few classifications of "risk," relying on some of its features (Aven, 2012; Aven et al., 2011; Aven & Renn, 2009).

To quote one of these, Hansson (2004, 2013) identifies five senses of risk:

1. An unwanted event that may or may not occur;
2. The cause of an unwanted event that may or may not occur;
3. The probability of an unwanted event that may or may not occur;
4. The statistical expectation value of an unwanted event that may or may not occur;
5. The fact that the decision is made under conditions of known probabilities.

Nonetheless, there are different definitions of risk, and they all have in common two characteristics, i.e., the potentiality and the adversity of the event or the outcome (Boholm et al., 2016). Furthermore, Hansson (2004, 2013) sustains that, other characteristics common to all the definitions of the concept of "risk" are the lack of knowledge and the constant uncertainty of the outcome.

### 2.1.1 The dualism of risk: objective and subjective risk

Referring to the definitions of the concept of "risk" above, what is relevant are two aspects: the objectivity resulting from physical facts (i.e., the probability of occurring of an unwanted outcome) and the subjectivity given by a social construction (i.e., something that is valuable for humans). The objective risk theory states that the risk is the probability or the chance to occur of facts of the physical world, whereas facts of the physical world are not considered objective facts about values (e.g., moral issues about the truth). On the other hand, the subjective risk theory states that the risk is the result of social construction in which the world has a marginal role (Hansson, 2010).

In spite of this distinction of risk, some scholars have sustained a more ontological point of view according to which the risk is fact-laden. From this point of view, the risk is a construction of the world and every kind of risk exists objectively, relying on the fact that nobody can predict the probability of an outcome (Aven et al., 2011). On the other hand, other social sciences scholars stated that risk is only subjective, so it is value-laden (Slovic, 1992; Slovic & Weber, 2013; Weber, 2001). Hence, the subjective risk could not be independent of people's minds and opinions, becoming a human mind construct created to cope with risks and unknowns. Accordingly, the cause of the risk is the only intrinsically objective aspect (Slovic & Weber, 2013). Slovic (1992, 1999) took the most extreme position stating that there is no objective risk but only a subjective description.

Finally, there is a third view of the objective and subjective risk, which combine the two. Thus, the risk is defined as a concept that refers both to objective and subjective facts (Hansson, 2010).

## 2.2 What is risk perception?

### 2.2.1 Risk-as-analysis and risk-as-feelings

When people encounter a risk, they assess it by responding to the hazard that they are perceiving. From a cognitive point of view, risk perception is highly demanding and could activate the "analytic system" or the "experiential system." According to the dual-process theories, these two systems work in parallel but are triggered from two different inputs and respond to two distinct working mechanisms (Epstein, 1994). The "analytic system" requires normative inputs to be activated, such as statistics and algorithms, and it follows logic statements. In addition, it is slow because it is cognitively effortful and requires constant cognitive awareness (Epstein, 1994; Slovic et al., 2004). Referring to the risk perception field, people use this system when they bear the hazard through logic statements, statistics data, and scientific assumptions ("risk-as-analysis"). Thus, the perception of "risk-as-analysis" relies on statistics and data of the considered risk, and for this reason, it is more associated with the risk perception of experts (Slovic, Fischhoff, & Lichtenstein, 1981; Slovic et al., 2004). Indeed, laypeople usually base their risk assessments on environmental information, which leads them to make some intuitions, inferences, or even react instinctively to the hazard perceived. As a matter of fact, this second response to risk is known as the "risk-as-feelings" perception and enables people to understand whether the risk is acceptable or not (e.g., drinking strange-smelling water or talking with a stranger person; Loewenstein et al., 2001; Slovic & Weber, 2013). This latter risk perception relies on the activation of the second cognitive system of the "dual-process theories" which is the "experiential system". This cognitive system is intuitive, fast, automatic, and relies on associations. The "experiential system" is activated by positive or negative emotions linked to people's experiences (Epstein, 1994; Slovic et al., 2004; Slovic & Weber, 2013). People use emotions as cues to lead their decision-making process in risky situations, those that leave a neurological trace - called somatic marker - are linked to the valence of the feeling proved when the somatic marker has been created (Damasio, 1994).

### 2.2.2 The Psychometric paradigm: the cognitive map of risks

Many scholars proposed different approaches to study risk perception, considering the above differentiation between "risk-as-feelings" and "risk-as-analysis" (Douglas & Wildavsky, 1982; Fischhoff et al., 1978; Kasperson et al., 1988; Loewenstein et al., 2001). One of the most famous approaches is the psychometric paradigm (Fischhoff et al., 1978; Slovic, 1987). The Psychometric paradigm has been developed by Slovic, et al. (1978) with the purpose to create a taxonomy of risks to understand and predict the responses to hazards (Fischhoff et al., 1978; Slovic et al., 1980; Slovic, 1987; Slovic & Weber, 2013). This approach is based on quantitative judgments of the perceived and desired riskiness of different hazards and the willingness to control them. Therefore, these quantitative judgments are transformed into quantitative representations of the risk attitude or "cognitive maps" of risks through psychophysical scaling and multivariate analysis techniques (Slovic et al., 1981; Slovic & Weber, 2013). In the first version of this paradigm, Fischhoff et al. (1978) found that the perception of risks between experts and laypeople was strictly connected to the meaning of "risk." The former judged risks using a quantitative perspective, for example likelihood. In comparison, the latter based their judgments on a qualitative perspective of risks, such as "level of knowledge of the risk," "controllability," "severity of consequences," "dread," "involuntariness," "latency of the risk," "catastrophic effects of the risk," "newness" (Fischhoff et al., 1978; Slovic et al., 1980, 1981; Slovic, 1987; Slovic & Weber, 2013). Fischhoff et al. (1978) discovered that many qualitative judgments of risks correlated with each other and for a vast array of hazards. Thus, using a means of factor analysis, they have been aggregated in higher-order psychological factors: “dread risks” and “unknown risk” (Slovic et al., 1981; Slovic, 1987; Slovic & Weber, 2013). The “dread risks” factor includes all the hazards perceived as lacking control, dreadful, with catastrophic potential, and having fatal consequences (e.g., nuclear power; Slovic et al., 1981; Slovic & Peters, 2006; Slovic & Weber, 2013). While the “unknown risk” factor groups all the risks perceived as new, unknown (to science), unobservable, and with delayed effects (e.g., chemical and DNA technologies; Slovic, 1987; Slovic & Weber, 2013). The two psychological factors are in perpendicular relation, and both have two opposite poles. This spatial connotation shapes the “cognitive maps” that Fischhoff et al. (1978) proposed first, then Slovic (1987) subsequently applied to the perception of 81 different hazards (see Figure 1).

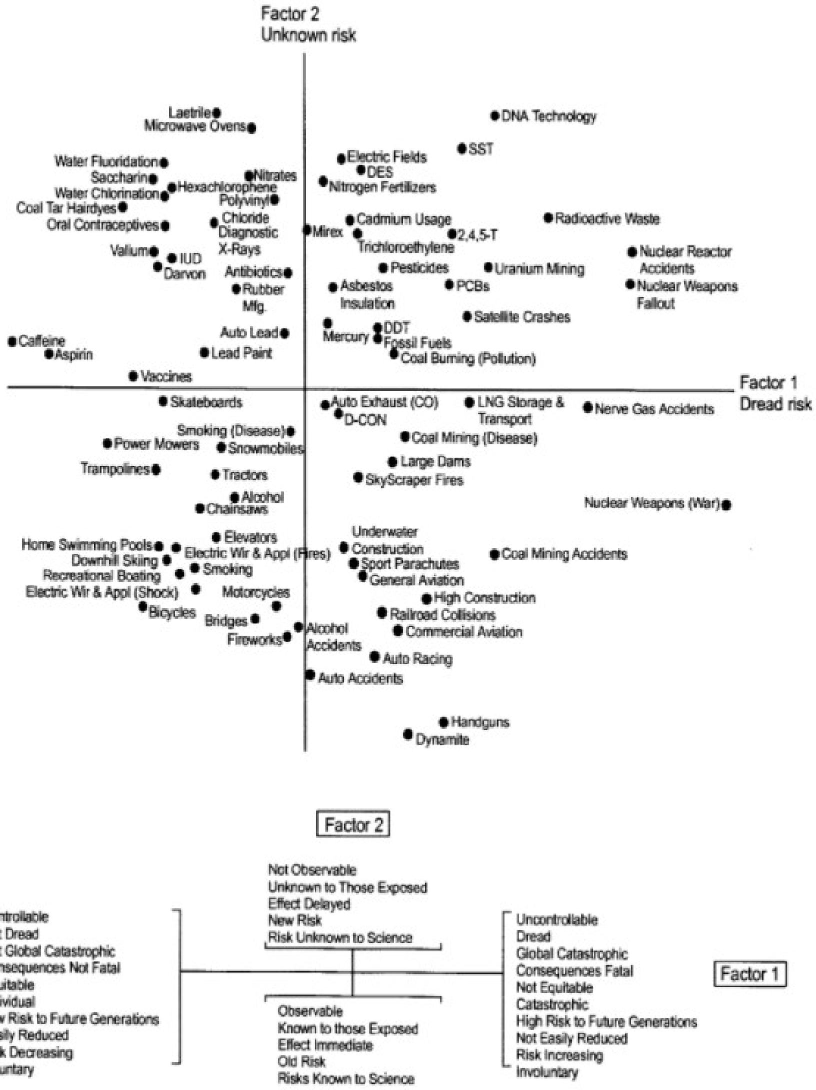



**Figure 1.** Location of 81 hazards derived from the intercorrelation of 15 risk characteristics that constitute the two factors of division (Factor 1 and Factor 2), as indicated in the lower diagram (Source: Slovic, 1987).

The position of risks along these two factors defines the hazards' riskiness and people's attitude to reduce the risk perceived (Slovic, 1987; Slovic & Weber, 2013). Thus, the higher is perceived the risk on both the "dread risks" factor and the "unknown risks" factor, the higher is the general risk perception of the hazard considered and the attitude to bear it (Slovic et al., 1981; Slovic, 1987; Slovic & Weber, 2013). Thus, risks that figure in the upper-right quadrant of the "cognitive map of risks" are the ones perceived as the most risky. On the contrary, experts' judgment of riskiness is connected to the concept of risk they learned; thus, it refers more to mortality rate than risk's characteristics (Slovic, 1987).

### 2.2.3 The affect heuristic

In literature, it has been demonstrated the relevant role of feelings in risk perception (Fischhoff et al. 1978; Slovic, 1987). We refer to affect as the specific quality of ''goodness'' or ''badness'' experienced in a feeling state (with or without consciousness) and defines a positive or negative quality of a stimulus (Slovic & Peters, 2006). As explained above, affect is central in risk assessment and it helps people to bear a hazard in a faster and easier way activating the "experiential system". To refer to the reliance on these feelings, we use the term "affect heuristic" (Slovic & al., 2002, 2004; Slovic & Peters, 2006), i.e., a cognitive shortcut that exploits the affect attached to a risk to assess it. In particular, there is an inverse relationship between the risk (e.g., nuclear power) and the affect: when they are negatively correlated, people judge the risk as high and the benefits as low, while when they are positively correlated, people judge the risk and the benefits vice versa (see Figure 2; Slovic et al., 2004; Slovic & Peters, 2006).

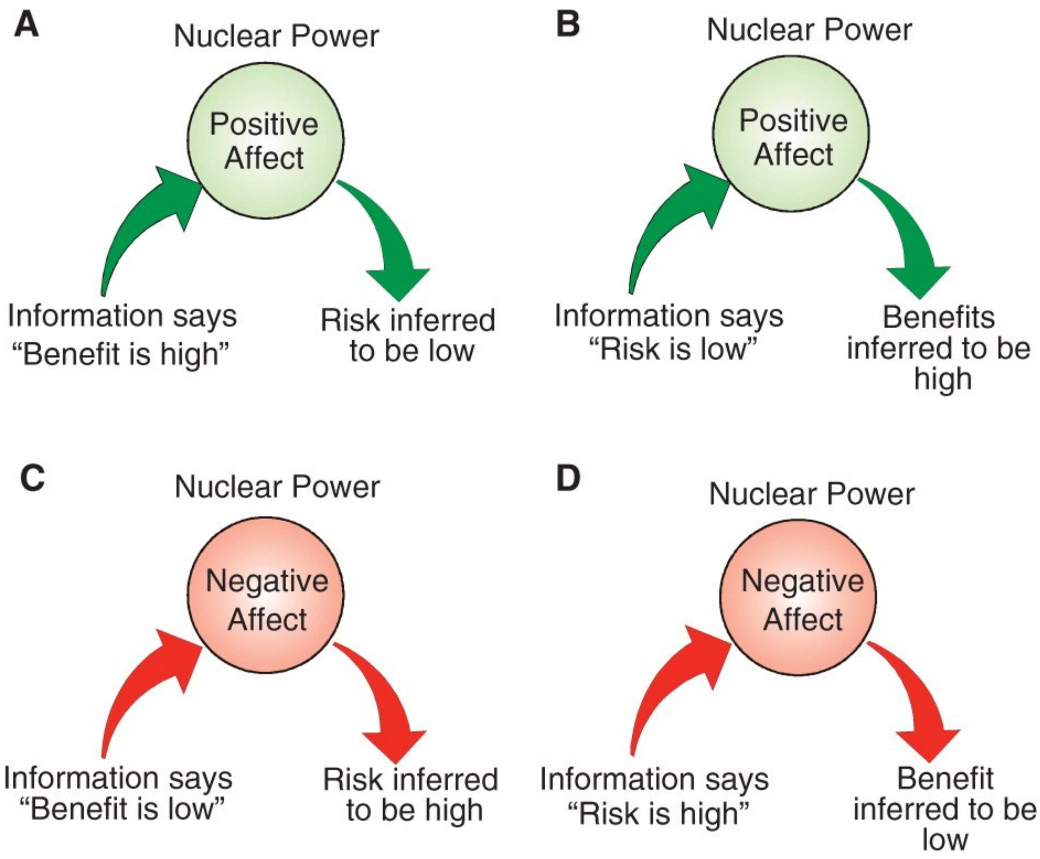



**Figure 2.** A representation, based on the affect heuristic, where the benefits (A) or the information (B) given, coincide with the affect, increasing the positive evaluation and inferences of the risk. Similarly, information about the benefit (C) or the risk (D) consistent with the negative affect shape negatively the consequent inferences. (Source: Slovic, 1987).

In literature, many scholars support the thesis that the inverse relationship between affect and judgment of risk and its benefits is due to an overall affective reaction to the risk: people tend to judge risks and benefits together activating a "general" evaluation of the risk (Alhakami & Slovic, 1994; Finucane, 2000A; Zajonc, 1980). As a matter of fact, this is known as the "halo effect" which explains people's different attitudes towards situations, objects, or people relying on the assessments' valence (i.e. positive or negative) of a single characteristic of the object of reference (Alhakami & Slovic, 1994; Finucane, 2000A). Finucane et al. (2000A) proposed two experiments to prove the mediating effect of affect on the judgment of risk and its benefits depending on the information given. The first experiment had four conditions. The manipulated factor was the type of information given to participants (affective information: high vs. low risk and high vs. low benefit) about three technologies (i.e., nuclear power, food preservatives, and natural gas). So that, these would have increased or decreased the perceived benefits or risk. Results were in favour of the theory of affect heuristic. The second experiment was designed to induce a rapid answer in participants. The underlying hypothesis was that in a condition of scarcity of time the affective response, and in consequence, the perception of risk and inverse related benefits, was higher than in normal conditions with no time constraints. In this second experiment, the results supported the hypothesis too (Finucane et al., 2000A; Slovic et al., 2004; Slovic & Peters, 2006). Thus, the affect heuristic directly impacts the judgment of risks (Finucane et al., 2000A). The explanation of these results is that the affect's role in risk perception is greater than the one of the analytic system (Peters & Slovic, 2000) because the former triggers the experiential system (Epstein, 1994; Slovic et al., 2004). Otherwise, this is not the case in risky and uncertain situations, because the emotional and visceral responses are faster (Damasio, 1994). It should be emphasised that, in the scientific literature the affect heuristic is not considered only as a predictor of risk perception but, on the contrary, the result of a cognitive process (Lazarus, 1981, 1984; van der Linden, 2014). Lazarus (1981, 1984) states that events are previously recognized and associated with past experiences and personal values. Then, after this latter association has occurred, the affective response emerges. The purpose of the “affect as a post-cognitive process” paradigm was to explain why people perceive different emotions in the same situation (e.g., climate change; van der Linden, 2014). In contrast to the affect heuristic, between perceived risk and affect there is a direct causal relation. Thus, personal experience with extreme weather events determines a higher risk perception of climate change and, as a result, an associated negative affect (van der Linden, 2014).

### 2.3 Risk perception of climate change

Thanks to the "cognitive map" it is possible to compare the perception of different risks among different groups (Slovic, 1987; Slovic & Weber 2013). We wanted to study and compare the perception of two risks, i.e., climate change and the SARS-CoV-2 pandemic. In our case, the psychometric paradigm was insufficient to explain all the variables involved in climate change perception, for example. Indeed, this paradigm explains risk perception relying on cognitive and emotional variables, while climate change involves a more complex range of factors that includes also socio-demographic, cultural, experiential factors, and typical heuristics and biases (van der Linden, 2017). The characteristics of climate change make it an uncommon phenomenon. Indeed, climate change is a global problem completely caused by humans (Breakwell, 2010). Despite the majority of the scientific community agreeing on the latter, not all people agree that climate change is a human-caused problem. In fact, only six out of ten Americans agreed with the scientific community by stating that climate change is happening due to humans (Leiserowitz et al., 2020). The diversity in perceiving climate change is linked to cultural, political, and personal views (Douglas & Wildavsky, 1982; Kahan, 2012), which partially explains the differentiation of climate change perception from country to country. Therefore, despite climate change being a global issue, the majority of developed countries perceived it as less risky and imminent than the developing countries (Kim & Wolinsky-Nahmias, 2014; Lee et al., 2015; Leiserowitz, 2007). Some variables implicated are the economic wealth of the country, which has a negative correlation with the concern about climate change (Kim & Wolinsky-Nahmias, 2014). The national economic development decreases the climate change concern because it could be that environmental protection is not a materialistic issue for developed countries, instead, it should be for the developing ones because it directly affects the foundations of welfare (Dunlap & York, 2008). Another difference is linked to the geographical area of each country; thus, some countries are more likely to be subjected to extreme weather and others are already coping with the everyday extreme consequences of climate change (i.e., drought, intense storms; Kim & Wolinsky-Nahmias, 2014). When comparing climate change with different risks, it is perceived as a low-action needed risk. In fact, climate change is a long-term problem with cumulative, long-lasting effects thus enabling people to conceptualize it as an abstract issue that determines a low sense of urgency to act (Weber, 2010). The dilation of action to reduce climate change is due to a perception of present costs which are higher than the unknown future benefits, thus leading people to be less proactive in reducing climate change (Weber, 2006, 2010). For example, people are aware of the necessity to reduce the $CO_2$ emissions, but the contribution is required in a short-term period while the results are visible in the long-term (Milinski et al., 2008). At the same time, climate change perception is personal and affected by personal past experiences. Leiserowitz (2006) studied the emotional response linked to climate change exploiting the "cognitive map of risks". His results revealed that risk perception of climate change and so its position on the "cognitive map of risks" was correlated to having (or not) previous negative experiences with climate change. Whereas being exposed to an extreme risk increases risk perception, not having been exposed to climate change before led to a lower negative connotation (Weber, 2010).

### 2.3.1 The "Climate Change Risk Perception Model"

To assess climate change risk perception we relied on van der Linden's "Climate Change Risk Perception Model" (CCRPM), which combines fifth theoretical dimensions, i.e., "cognitive", "experiential", "socio-cultural", "socio-demographic" and "heuristics and biases" factors to explain the variation in climate change risk perception (Figure 3; van der Linden, 2017).

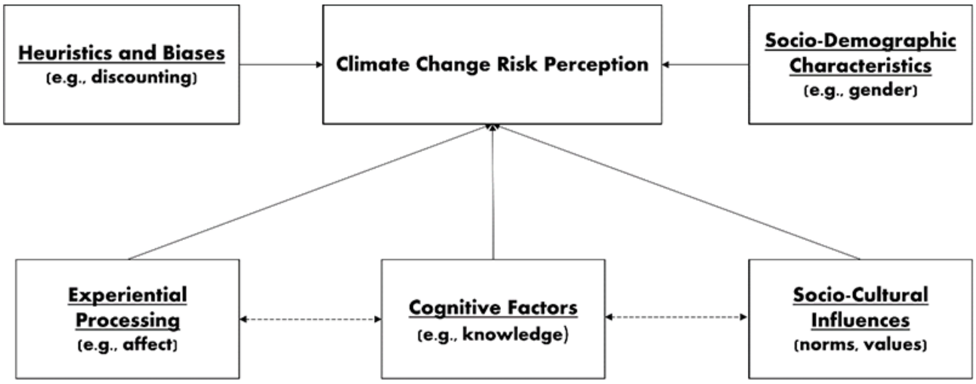



**Figure 3.** The Climate Change Risk Perception Model (CCRPM) by van der Linden assesses the different variables implicated in climate change risk perception (Source: van der Linden, 2017).

The "cognitive" factor considers the concept of knowledge as a predictor of risk perception subdividing it into three types: knowledge about the causes and the physical mechanism underlying climate change (declarative knowledge); knowledge about impacts and consequences of climate change; and knowledge about how to face climate change and find new solutions (procedural knowledge; van der Linden, 2017). These three types of knowledge have a different degree of influence on climate change risk perception, with the "procedural" knowledge being the most influential in shaping risk perception (Shi et al., 2016; van der Linden, 2015A). At the same time, people should have all these three types of knowledge about the risk to have a significant risk perception (van der Linden, 2015). To determine the role of knowledge on climate change risk perception worldwide, Shi et al. (2016) conducted an international survey in 6 countries. They found a direct relationship between knowledge about the causes of climate change and level of concern, while there was no significant effect between knowledge of physical characteristics of climate change and level of concern. In addition, in scientific literature, it has been demonstrated that there is an unreliable relationship between self-reported knowledge about climate change and scientific knowledge about it (Shi et al., 2016) that has to be assigned to the difference of what people believe to know about climate change and their scientific knowledge about this issue. Indeed, it has been revealed that scientific knowledge tends to contain the effects of worldviews and cultural influences on climate change effects (Guy et al., 2014; Kahan, 2012). Guy et al. (2014) found—using objective measures—that greater knowledge actually attenuates the (negative) effect of ideological worldviews, resulting in a positive relationship between more knowledge about climate change and public concern. Otherwise, having knowledge about climate change does not explain the personal variance of risk perception and explains just a little percentage (almost 10%) of the public concern about this risk (van der Linden, 2015).

The "cognitive" factor explains a part of the risk perception of climate change, but the main predictor is the "experiential" factor that considers both the affect associated with risks and the personal experiences. As explained above in "risk-as-feelings" response to risk, both affect and personal experiences are central to determining risk perception (Loewenstein et al., 2001). Moreover, the relationship between affect and perception of climate change is by-directional and context-dependent (van der Linden, 2014). An explanation to this reciprocal influence between affect and climate change is given by the neurobiological evidence where it is claimed that in front of extreme danger (e.g., tornados) people activate both the experiential systems (i.e. perceived risk) and the analytical system (i.e. information about the hazard; LeDoux, 1989) to face the extreme event. Thus, when people are directly experiencing climate change effects (i.e. hurricanes, earthquakes, floodings, etc.), they are providing an affect response simultaneously and categorizing them as a risk (van der Linden, 2014); so that the cognitive and the affective reactions influence each other (LeDoux, 1989). In particular, the affect associated with climate change is negative and predicts global warming risk perception (see Figure 4; Smith & Leiserowitz, 2012). In this context, the affective response to climate change is negative because it is related to extreme climate change events (i.e. hurricanes, earthquakes, floodings, etc.), which affects risk perception too (van der Linden, 2014; Weber, 2010).


**Figure 4.** Model of by-directional influence of the personal experience of extreme weather and negative affect on climate change risk perception. (Source: van der Linden, 2014).

Notwithstanding, extreme weather does not occur daily and people's climate change risk perception is context-dependent (van der Linden, 2014). Indeed, climate change is an atypical risk, because it does not have environmental and physical cues to get perceived so dangerous to trigger a visceral fight-or-flight response (van der Linden, 2014; Weber, 2006), leading to an opposite response between analytical and emotional-based systems. Thus, the typical answer to climate change is guided by affect (Lowenstein, 2001). All this is more relevant if climate change effects affect the area in which the person lives (Myers et al., 2012).

The peculiarity of the CCRPM is to consider the sociological aspect of risk perception. This novelty is declined as both "socio-cultural" and "socio-demographic" factors. The reason to include the societal aspects is that there are different studies in the scientific literature supporting the influence of media communication (Weber, 2010), societal norms (van der Linden, 2015), and interpersonal relations on climate change risk perception (van der Linden, 2015). In particular, people tend to align their climate change risk perception to the one of their society and the perception of climate change as a serious risk is as higher as the one of the closest social groups, such as friends and family (van der Linden, 2015). In other words, "descriptive" (i.e., the perception of a prevalent behavior among group members) and "prescriptive" (i.e., ought to think or behave to have the significant ones' approval) norms of a social group influence global warming risk perception (Cialdini & Jacobson, 2021; van der Linden, 2015, 2017). Given these premises, it is necessary to consider the "socio-cultural" factor of van der Linden's model because according to "the cultural theory of risk" (Douglas, 1970; Douglas & Wildavsky, 1982) the strength to which an individual is linked to its culture by a feeling of belongingness (group) and the level of control and structure that he maintained in his societal role (grid), determine his position on a risk-culture system of risks perception (i.e., egalitarianism, individualism, hierarchism, fatalism; van der Linden 2015, 2017). Moreover, according to the "cultural cognition thesis" (Kahan, 2012), people tend to accept or deny scientific evidence about climate change risks on societal level depending on whether they are coherent or not with its cultural values. Indeed, different climate change warnings are overwhelmed when are in line with people's cultural predisposition of the risk (Kahan, 2012). It is important to underlying that "values", "worldviews" and "culture" are not interchangeable concepts (van der Linden, 2015, 2017). "Values" precede "worldviews" being their basing principles (van der Linden, 2015). At the same time, "culture" and "values" almost overlap, because the former is characterized by a structure of values that is different considering different cultures (van der Linden, 2015, 2017). Thus, each culture has a characterizing structure of values that prioritize one or another. For the environment field, these values are: egoistic values (i.e. projected to the individual interest), socio-altruistic values (i.e. projecting to others' interests), and biospheric values (i.e. caring for nature and non-human itself). The values are not mutually exclusive and it has been demonstrated that the more people have egoistic values, so self-identity (Bouman et al., 2021), the more they predicted risk perception and pro-environmental actions (Bouman et al., 2021; van der Linden, 2015). Hence, people have a bias of underestimation of others in favour of themselves caring the most about climate change (Bounman et al., 2021). On the contrary, when a culture has strong socio-altruistic values, such values go in contrast with the biospheric ones (van der Linden, 2015). The reason is that the biospheric values are more salient in climate change (van der Linden, 2015) than socio-altruistic values which activate the biased underestimation of others' biospheric values, discouraging any form of pro-environmental action (Bouman et al., 2021).

With regard to, the "socio-demographic" factor, it explains a little variance of risk perception. Indeed, this factor considers the impact of variables as income, age, education level, religion, race, political orientation, and gender on climate change perception. However, these socio-demographic variables have little direct impact on climate change risk perception (Leiserowitz, 2006; van der Linden, 2015). This little impact of socio-demographic variables is due to a stable correlation among race, political orientation, and gender (Finucane et al., 2000B; Leiserowitz, 2006). These latters are implicated in an effect known as the "White male" effect, which has been demonstrated first in the general field of judgment of risk perception and in the climate change context too (Finucane et al., 2000B; Kahan, 2012; Kahan et al., 2007; van der Linden, 2017). It explains a stable underestimation of risks for conservative white male compared to ethic minorities and females. Kahan et al. (2007) had discovered that, in the context of climate change, white males tend to ignore the climate change warnings because these latters implicitly attack their positions in society (i.e., the higher one) thus white males have more of a stake in protecting their social positions than the climate. Considering the hierarchical position of women, who are seen as caregivers and mothers with domestic roles (Kahan, 2012; Kahan et al., 2007), two theories - the "Social Roles" and the "Safety Concern Hypothesis" - have been proposed and they state that women's social role enables them to develop a higher concern for health and safety (Davidson & Freudenburg,1996), leading them to have a higher concern for the environment and climate change too. Few researches have shown that ethnic minorities are usually subjected to a higher general sense of risk due to their vulnerability caused by constant environmental stress (Mohai & Bryant, 1998; van der Linden, 2017).

Finally, the last factor of CCRPM is the "heuristics and biases" factor. In general, people use heuristics and biases to simplify their cognitive processes. Indeed, they are shortcuts that enable people both to save cognitive energy and to find simpler solutions to difficult tasks (Slovic et al.,1980, 1981). They are useful until the practical solution that they provide mismatches with the real world. Unfortunately, this last sentence describes the heuristics in an environmental context that lead to a misperception of climate change and prevent action against its diffusion (van der Linden, 2017; Zhao & Luo, 2021). Some of the most known biases that have a role in climate change are the temporal discounting bias, the intergenerational discounting bias, and the optimistic bias. The temporal discounting bias is the tendency to place less value in the uncertain future consequences of a phenomenon (e.g., climate change) due to its temporal distance from the present (Hardisty & Weber, 2009). Under this bias, people tend to underestimate future risks of a discount which increases with the time-distance of the risk following a hyperbolic trend (Berns et al., 2007). One possible cause of this misperception of risks is bio-evolutional:

people were not used to having a long span life so they preferred an immediate reward rather than a delayed one and the discount of future was even higher when the variables at play were uncertain or risky compared to the ones available in their present (van Vugt et al., 2014). On the contrary, people's life expectancy has increased and we face long-lasting problems, like climate change, which is not perceived as a present problem because its representation is more abstract lacking of association with present consequences (i.e. climate change causes global warming) leading to a less intense emotional answer (e.g., fear; Weber, 2010). These characteristics of climate change perception are linked to a second bias, hence the "inter-generational discounting". Indeed, not being able to perceive clearly the consequences of long-lasting risks (e.g., climate change), lead to the tendency to weigh less the benefits that the future generations will get rather than the costs of own's generation in the present. Acting to mitigate climate change is perceived as a cost in the present to see benefits in the future and the current generation (maybe) is not the one that will get benefits from these sacrifices (i.e. actions to reduce the emissions of $CO_2$; Weber, 2010). Moreover, people tend to judge climate change as more likely and riskier for others and distant places than for themselves (van der Linden, 2015). This last misperception of climate change effects is in part due to the third bias of this section: the "optimism bias" which leads people to overestimate positive outcomes and underestimate the likelihood of facing negative events (Sharot, 2011; Weinstein; 1989). For example, there is a link between spatial bias and optimism bias for which, in general, closest conditions are more beneficial than the distal ones (Gifford et al., 2009). Therefore, environmental quality judgments assume a negative valence as the spatial scale expands from local to global (Schultz et al., 2005; Uzzell, 2000). Moreover, it has been demonstrated that people esteem their local area as safer from extreme climate change events than the one of peers (Haltfield & Job, 2001; Pahl et al., 2005).

### 2.4 Risk perception of SARS-CoV-2 pandemic

SARS-CoV-2 pandemic is a novelty for the global population and it is revolutionizing how people perceive this risk. People usually exploit the consequences of their actions to reduce a hazard (Slovic, 1987). But this is not the case for the SARS-CoV-2 pandemic. In fact, a peculiar characteristic of the SARS-CoV-2 virus is that the outcome of people's actions in the near future is not only unpredictable and uncertain (Cori et al., 2020), but also typical actions (e.g., doing grocery shopping, sharing meals with families, or taking public transport) suddenly became potential actions of contagions to spread the virus, where everybody could be the "first" positive contact inducing in people a higher sense of constant uncertainty and anxiety (Shevlin et al., 2020). The state of uncertainty given by the SARS-CoV-2 was due to the unpredictability of the spreading of this virus itself (Rubaltelli et al., 2020). Indeed, among SARS-CoV-2 positive people, there are asymptomatic patients, people who do not respect government restrictions, and, from the scientific point of view, the knowledge and medical protocols to cure the virus were limited, mostly in the first months of the pandemic. These specific elements of the SARS-CoV-2 virus, collocate it in the upper-right draft-unknown quadrant of the "cognitive map of risks," among the hazards perceived as the riskiest (Slovic, 1987). Moreover, the SARS-CoV-2 pandemic was a lifechanging event for which all the government had to implement the protective behaviors suggested by the World Health Organization (WHO; Zarocostas, 2020) and implement more or less strict preventive norms, such as the national lockdown, the use of masks outside or authorizing exits for proven needs. Worldwide, people adapted their lives to these new restrictions to prevent the collapse of their national health system under the pressure of an unknown highly contagious deadly disease (Zarocostas, 2020). On the other hand, since the outbreak of the pandemic, scientific knowledge and protective behaviors improved, helping people to manage the risk of contagion and to reduce the perceived risk of this novelty virus, consequently lowering and nearing to the axes its respective position of riskiness on the "cognitive map of risks" (Weßel, 2021; Wong & Yang, 2021). The recent psychological literature has provided some studies to identify which are the variables that impact the risk perception of the SARS-CoV-2 pandemic and the willingness to follow the protective and preventive measures (Caserotti et al., 2022; Dryhurst et al., 2020; He et al., 2021; Savadori & Lauriola, 2021). The most interesting study for the design of our own is the one conducted by Dryhurst et al. (2020) where they adapted the van der Linden's CCRPM model to the SARS-CoV-2 pandemic. In fact, the purpose was to find which were the variables behind the risk perception of the SARS-CoV-2 pandemic in a worldwide sample of 10 different countries relying on a theoretical base (Dryhurst et al., 2020). Thus, they collected data of affective, cognitive, social/cultural norms as dimensions of risk perception and socio-demographic personal differences relevant in risk perception. The affective dimension included the emotional and experiential factors of the CCRPM, and those items were related to personal experiences and the concern about the risk. For example, they specifically asked their participants to answered their level of worry for the SARS-CoV-2 pandemic situation and if they have ever got the virus or thought to have it (Dryhurst et al., 2020). Although the literature about people's response to pandemics is almost a novelty compared with the ones of the response to other risk domains (de Zwart et al., 2009), it has been demonstrated the role of previous experiences in the SARS-CoV-2 pandemic (Dryhurst et al., 2020; Gerhold, 2020; He et al., 2021). Specifically, people who have been exposed to the SARS-CoV-2 pandemic perceive a higher level of risk compared to people who have not been directly exposed to the SARS-CoV-2 pandemic (Dryhust et al., 2020; Gerhold, 2020). This is in line with the somatic marker theory (Damasio, 1994) and the affect heuristic (Slovic & al., 2002, 2004; Slovic & Peters, 2006; see paragraph 2.3.3. The affect heuristic to have more details). Moreover, it has been demonstrated that the indirect experience with the SARS-CoV-2 pandemic increases the level of risk perception as well. In fact, receiving information from media or the close group of people (He et al., 2021; Rubaltelli et al., 2020) about the rate of death, the number of positive cases, and general suffering associated with the SARS-CoV-2 increased the negative affect (Gerhold, 2020; He et al., 2021; Schneider et al., 2021A), the risk perception (Rubaltelli et al., 2020; Dryhust et al., 2020) and reduced the number of protective behaviors (Rubaltelli et al., 2020). Rubaltelli et al. (2020) highlighted the mediation role of emotion regulation on the number of protective behaviors undertaken by people. In fact, in the Italian sample during the national lockdown, people who were able to regulate their emotions enacted the necessary protective behaviors independently from the risk perception. On the contrary, those who were not able to regulate their emotion engages in the protective behaviors was related on the risk perception level: higher number of protective behaviors corresponded to higher level of risk perception (Rubaltelli et al., 2020). In general, emotions are associated negatively with risk perception of the ongoing pandemic, in addition, the latter is negatively associated with personal psychological factors (e.g., depression, anxiety, boredom, nervousness, loneliness, and exhaustion; Han et al., 2021; Rubaltelli et al., 2020). What is really interesting is that in general risk perception of the SARS-CoV-2 pandemic is more associated with psychological factors than objective ones (Schneider et al., 2021A).

In the Dryhurst et al. (2020) international study they considered a second psychological predictor of risk perception of the SARS-CoV-2 pandemic: the cognition declined with items about personal and social knowledge about the risk considered. Personal knowledge is the understanding of government measurement to contrast the SARS-CoV-2 pandemic, while social knowledge is the belief in scientific opinion regarding the virus (Schneider, 2021A). Personal knowledge was positively related to risk perception, thus increasing the information about the SARS-CoV-2 pandemic directly increased the risk perception (Dryhusrt et al., 2020; Zhong et al., 2021). This is due to the type of messages that the mass media spread during the pandemic and to the source of information. He et al. (2021) found that the risk perception level changed relying on the source of information: it was lower when the information about the SARS-CoV-2 pandemic came from friends and families through chat groups. In line with this finding, Zhong et al. (2021) suggested that the messages of social media during pandemics should focus more on the psychological support of individuals than only aware them on the objective situation of the SARS-CoV-2 pandemic (e.g. new positive cases daily rates, deaths rates). On the contrary, Schneider (2021A) did not find any correlation between personal and social knowledge and risk perception. In addition, it has also been found a negative correlation between social knowledge and risk perception, thus the more a person inquiry from a scientific source the more this increases the risk perception (Zhong et al, 2021).

Linked to the latter there is another factor considered by Dryhurst et al. (2020) that is the trust. Trust is not a variable previously considered in the reference model of van der Linden (CCRPM), but it was highly recommended to add it relying on the previous literature about pandemics (de Zwart et al., 2009; Prati & Pietrantoni, 2016). Trust has been investigated as trust in government, trust in science and trust in medical professionals (Dryhurst, 2020). Trust in science and trust in medical professionals were positively correlated with risk perception, while trust in government was negatively correlated with it (Dryhurst, 2020). Despite it has been reported that the higher is the level of scientific knowledge about the SARS-CoV-2 pandemic the higher is the risk perceived, people believe that the medical professionals are the most reliable (Gerhold, 2020; Zhong et al., 2021). At the same time, it has been demonstrated that people who trust science and government more, are more willing to use pharmacological (i.e. get the vaccine) and non-

pharmacological (i.e. download a Contact Tracing App Immuni) tools to defeat the virus (Caserotti et al., 2022). Relying on a previous work of Xie et al. (2019) whose topic was climate change, efficacy was added as second element of implementation of the CCRPM model. Efficacy is the believe that the available actions are useful to reduce or control a threat (e.g., the measurement imposed by governments to defeat the SARS-CoV-2 pandemic; Rogers, 1983). In the model by Dryhurst et al. (2020) efficacy had been studied as both personal and collective efficacy, and the former referred to the perceived efficacy of personal adherence to the government measures while the latter to the perceived efficacy of other people respecting such measures. It has been demonstrated that the efficacy, in both these two components, had a different role depending on the country. In

general, the personal efficacy explained a higher level of variance among the countries than the collective efficacy. But specifically, personal efficacy emerged as a significant predictor of risk perception of the SARS-CoV-2 pandemic for Germany and Sweden, while collective efficacy was a relevant predictor for Japan, Mexico, and USA (Dryhurst et al., 2020). To sum up, the role of efficacy as predictor of risk perception of the SARS-CoV-2 pandemic was not so significant, although it reduced the SARS-CoV-2 risk perception in the countries cited above (Dryhurst et al., 2020). In addition, the role of efficacy in different countries have been studied with previous pandemics and other diseases (i.e. SARS[1], HIV, high blood pressure, tuberculosis, common cold, and flu from a new virus; de Zwart et al., 2009) revealing how the European countries perceive a higher risk for the SARS than the Asian countries. This can be explained relying on the previous experience of the Asian countries with the disease, thus in case of an outbreak their efficacy beliefs declined as response efficacy (i.e. the extent to which people believe that the government's measurements are effective) and self-efficacy (i.e. the extent to which people believe they are able to undertake protective actions) are higher due to the previous similar context (de Zwart et al., 2009). A second explanation, that introduce the next factor of the model, is that the difference in efficacy response among countries relies on different cultural norms. Asian culture is more optimistic and believe in the cyclical perception of events, thus to a negative event follows a positive one, while Western cultures have not the same perception of the optimism bias (Ji et al., 2004). As mentioned, another factor is the cultural norms and culture values, to whom people adapt their beliefs of risks (Kahan, 2012). In particular, two cultural norms were significant in explaining perception of the SARS-CoV-2 pandemic, i.e., prosociality and individualistic worldview (Dryhurst et al., 2020). Prosociality is the measure to which people think that is important to do something to help others even if it requires a cost for themselves. From the Dryhurst et al. (2020) study emerged that the more prosocial people are the higher their risk perception is. On the contrary, individualism is the extent to which a person or a culture is self-focused. Related to the SARS-CoV-2 pandemic risk perception, it has been demonstrated that the more people have an individualistic worldview, the less they perceive the risk (Dryhurst et al., 2020). These two factors are responsible for the majority of the variance among the countries: United Kingdom (UK), Germany, Sweden, Spain and Japan were individualistic, while Italy, Mexico and Australia were prosocial (Dryhurst et al., 2020). A longitudinal study made in the UK, confirmed that the cultural tendency of being prosocial or individualistic is a major predictor of risk perception also within the same culture (Schneider et al., 2021A). In addition, in an Italian study, Savadori and Lauriola (2021) found that the individualism decreased the likelihood of being infected by the SARS-CoV-2 but not the affective response to such risk. In fact, people who trust more in government's measurements perceive a higher likelihood to be infected by the SARS-CoV-2 (Savadori & Lauriola, 2021). Finally, what emerged from the socio-demographic factors, is the presence of a gender effect: females perceived a higher risk than males (de Zwart et al., 2009; Dryhurst et al., 2020; Gerhold, 2020; Han et al., 2021; He et al., 2021; Rubaltelli et al., 2020; Schneider et al., 2021A; Zhong et al., 2021). This is contradictory with the fact that males' likelihood to be infected by the SARS-CoV-2 pandemic is higher than women' one (Gerhold, 2020; Jin et al., 2020). Moreover, considering the age, what emerged is that older people perceive less risk and lower likelihood to contract the SARS-CoV-2 pandemic compare to younger people (Gerhold, 2020) and the class age 40-50 is more doubtful to get the vaccine shot (Caserotti et al., 2022). Another socio-demographic factor that has been considered is the political orientation. Specifically, the recent literature has demonstrated that right-wing people have a higher risk perception of the SARS-CoV-2 pandemic than the left-wing people (Rubaltelli et al., 2020).

### 2.5 A comparison between two global issues: climate change and SARS-CoV-2 pandemic

The scientific community agrees stating that climate change is a global issue caused by humans actions (Oreskes, 2004; IPCC, 2014). Greenhouse emissions, fossil fuels use, and agriculture are among the main causes of the climate change which release in the atmosphere a high quantity of carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$; Alley et al., 2007; IPCC, 2014). In addition to this, some countries are more vulnerable than others to the long-term consequences of climate change (Kim & Wolinsky-Nahmias, 2014; Min et al., 2011; Zahran et al., 2008). The consequences of climate change involve both the environment and human health and deaths (World Health Organization. (2021). In these last two years we are coping with another global issue, hence the SARS-CoV-2. It is a virus that causes acute respiratory syndrome and spreads rapidly among people. First cases were reported at Wuhan, China during the end of December 2019 and beginning of January 2020, rapidly becoming the centre of an epidemy of SARS-CoV-2 (Lai et al., 2020). It rapidly spread outside national borders and on 11th March 2020, the World Health Organization (WHO) declared the state of "pandemic". This virus is highly contagious due to its period of incubation (2-14 days) and its symptoms similar to the flu (i.e., cough, fever, weakness, dysentery; Lai et al., 2020). The SARS-CoV-2 pandemic has been classified as one of the most catastrophic pandemics with more than 5 million deaths worldwide (World Health Organization). From this information about climate change and the SARS-CoV-2 pandemic, we can assess that they are both two global problems, but they have a main difference: while in the former case people can benefit from the reduction of emissions from other countries, in the latter case the reduction measurements of some countries cannot provide a significant benefit for people protection from the consequences of this virus in other countries (Fuentes et al., 2020). Both issues require a worldwide response, otherwise, the countries that delay the measures to contain climate change and/or the SARS-CoV-2 pandemic will be the free-riders of the ones who already prevent them. Indeed, the societal and economic disparity among countries is an obstacle that we have not been able to overcome during this pandemic situation. As a matter of fact, these disparities heightened between countries with efficient healthcare system and the possibility to afford the vaccines for their population and countries that had unstable and poor systems (Manzanedo & Manning, 2020). Climate change is a long-term generalized situation of this disparity: some countries enact the preventive measures to reduce the Greenhouse Gases (GHG) emissions while others do not (Fuentes et al., 2020). Another similarity between climate change and the SARS-CoV-2 pandemic is that they are both stock externalities, thus they create exponential problems if not resolved in time because they create long-term consequences (Fuentes et al., 2020). The SARS-CoV-2 pandemic's contagion speed increased the risk perception of a catastrophe since the beginning when the epidemiologists alerted everyone of the incoming pandemic. The same happened with climate change, but people are not so concerned about it and this is because of the different features of climate change compared to the ones of the SARS-CoV-2 pandemic that interact differently with the perception of the vulnerability of people, the hazard perception, and the risk perception (Pasini & Mazzocchi, 2020). This is even amplified if we consider the scientific knowledge shared with the population. Indeed, for both risks, the more people and politicians know, the less likely they are to act (Fuentes et al., 2020). This is more evident to climate change where the more governments know, the more funds are needed to deal with climate change (Manzanedo & Manning, 2020). While, for the SARS-CoV-2 pandemic, the behavioral response is prone to underestimating the risk (e.g. Brazil). This is linked to a cognitive bias known as "Not in my term office", for which politicians delay expensive actions to contain low-probability risk because the likelihood that they occur in their term is low and would be just a cost in terms of vows (Botzen et al., 2021). Finally, the SARS-CoV-2 pandemics and climate change are not simply two global issues with similar features, but instead they are interrelated. What emerged from the first period of lock-down, which affected almost all the world, is that the level of GHG emissions decreased drastically leading to an even major benefit to the environment which was reborn (Chakraborty & Maity, 2022). On the contrary, the level of single plastic use increased exponentially, and with it increased the problem of wasting (Mincer, 2021; Prata et al., 2020). Otherwise, from the behavioral level, we can learn something that seemed impossible to overcome hence a behavioral change to stop and reverse climate change. Indeed, the actual measures that governments are using are mitigation (i.e., delaying unwanted effects) and attenuation (i.e., reducing the upcoming consequences of humans' actions; Fuentes et al., 2020). And, finally, thanks to the SARS-

CoV-2 pandemic we saw that a readaptation of people's lives to the environmental needs is actually possible (Fuentes et al., 2020).

## 2.6. People's responses to risk perception from a societal level: cooperative behaviors

Cooperation is the willingness to help others even if this involves a personal disadvantage. Moreover, there is biological selection for cooperation that increments the cooperation among genetic partners than non-genetic-partners. Thus, the likelihood of cooperation increases when is going to benefit the loved ones (Hamilton, 1964). However, in the societal in-group can be established different types of cooperation relying on several relationships (e.g., friendship, dislike, gratitude, sympathy, trust, suspicious; Trivers, 1971). Thus, people show direct or indirect reciprocity. The former is the tendency to return a favour among the same individuals relying on a feeling of trust. This mechanism lasts till there is future reciprocity, otherwise, the level of cooperation decreases. Thus, direct reciprocity is the underlying mechanism of the one-shot social dilemma because there is no possibility to be rewarded from the cost since there is no other rounds (Fehr & Schmidt, 1999). While the indirect reciprocity involves an external party whose role is to give positive or negative retribution of the reputational level. Indeed, reputation is strongly activating when thinking about the future and, for this reason, indirect reciprocity is the strategy typically used in multi-shot social dilemmas (Fehr & Schmidt, 1999). The reputation effect in the future has been studied in the pro-environmental context, where it was discovered that legacies motives were strong predictors of pro-environmental behaviors (Zaval et al., 2015). In general, people cooperate more when they perceive the rewards in the long term as higher than the costs. In the cooperation, the main problem is that at the beginning people tend to be free-riders because they perceive the imminent cost as too heavy compared to the doubtful benefit (Chinazzi et al., 2020; Fehr & Schmidt, 1999). This is due to the fact that people are more focused on their present actions rather than on the future consequences of such actions (Chapman, 1996). But it has been demonstrated that there is a direct relation between feeling grateful and the consideration of future consequences. In particular, the more grateful people are, the more caring they will be for the future and the more they will cooperate. Thus, prosocial messages should focus on this positive feeling to enhance cooperation (Syropoulus & Markowitz, 2021). Moreover, the general role of affect and emotions has been demonstrated relevant in cooperative behaviors to cope with both climate change and the SARS-CoV-2 pandemic (Brosch, 2021; Capraro et al., 2021; Schneider et al., 2021B). Effective communication increases the likelihood of acting prosocially. Inducing a general sense of guilt for humans' role in climate change increases the likelihood to sign a petition (Rees et al., 2015). Otherwise, communication messages can stress a sense of compassion leading to higher support for environmental policies (Lu & Schuldt, 2016), or induce empathy toward suffering polar bears increasing donations to activists (Swim & Bloodhart, 2015). On the contrary, in the last years using the case of polar bears it has been demonstrated that non-environmentalist people are subjected to compassion fade while were looking to the photo of an identified polar bear than the photo of a population of polar bears, thus the mediation effect of the environmental identity is a boundary to face the high-demanding consequences of climate change (Markowitz et al., 2013). In contrast, regarding the SARS-CoV-2 pandemic, the urgent need to get large number of people to cooperate led behavioral scientists to look for effective ways to get as many people as possible to comply with preventive behaviors, such as social distance, wearing masks, washing their hands, and getting vaccinated. What emerged is that inducing empathy in social messages lead people to respect social distance more (Pfattheicher et al., 2020). Moreover, people's likelihood to wear a mask increases after telling them that they may otherwise be a danger primarily to their own community rather than to themselves

(Capraro & Barcelo, 2020). Finally, people's intention to get vaccinated increases hearing information about the beneficial effects of the vaccine, as herd immunity, even if they are highly in doubt to get it (Schwarzinger et al., 2021).

## 3. Experimental hypothesis.

The purpose of our study is to determine if and what kind of relationship there is between the exponential growth and risk perception, and the effects of this relationship on behaviors in the SARS-CoV-2 context in relation to climate change. Indeed, to extent of our knowledge, there is no evidence in the literature that this relationship has been investigated previously.

On the contrary, what is already known is that the SARS-CoV-2 pandemic and climate change are two global issues that people face and cope with. As previous literature showed, the SARS-CoV-2 pandemic and climate change have some common features: both of them have global effects, cause fatal health problems, have societal and economic effects, and need a unique worldwide answer (Botzen et al., 2021; Fuentes et al., 2020; Manzanedo & Manning, 2020; Pasini & Mazzocchi, 2020). Moreover, the scientific literature has demonstrated that they are interrelated, i.e. the SARS-CoV-2 pandemic impacted the $CO_2$ emissions (Andreoni, 2021; Fuentes et al., 2020) and the SARS-CoV-2 pandemic lead to an increment of single-use plastic products demands (Mincer, 2021; Prata et al., 2020). These similarities between the SARS-CoV-2 pandemic and the climate change are kept looking to the assessment's trends given by people: both follow an exponential growth (Pasini & Mazzocchi, 2020). Nonetheless, people are subjected to an exponential bias which leads them to linearize exponential growths when assessing them intuitively (Jones 1979; Wagenaar & Sagaria 1975; Wagenaar & Timmers 1979). In the present study, we decided to use the exponential bias of risk perceptions to compare between-subjects the risks considered (SARS-CoV-2 pandemic vs. climate change) in two different conditions (experimental vs. control). To the extent of our knowledge, there is the main difference in risk perception between SARS-CoV-2 pandemic and climate change in association with protective behaviors - in relation to the pandemic - (Brug et al., 2004; Vacondio et al., 2021) or preventive behaviors - in relation to climate change - . For climate change context the relation with preventive behaviors is not driven by a visceral response as it is previously claimed by different scholars (Leiserowitz, 2006; Weber, 2006). Thus, for the reasons above, in the present study, we hypothesized that risk perception of the SARS-CoV-2 pandemic is higher than the one for climate change leading to a higher number of cooperative behaviors. We investigated these hypotheses - Hypothesis 1a and 1b- through different levels. First, we investigated how risk perception changes considering temporal and spatial scales of action, because in literature there is evidence in favour of a general perception of climate change as being in the future and geographically distant (Leiserowitz et al., 2020; Weber, 2010). In addition, we studied the independent variable of risk perception relying on the likelihood of being impacted by climate change or the SARS-CoV-2 pandemic. Indeed, the literature suggests the role of optimism bias in diminishing the likelihood of being affected by the effects of a risk, in consequence, it reduces the perception of risk too (Sharot, 2011; Weinstein, 1989). Moreover, the characteristics of the risk itself change its perception in people's eyes (Slovic, 1987; Slovic, Fischhoff & Lichtenstein, 1981; Slovic & Weber, 2013) and for this reason, we added a question to investigate what is the direction of our sample's perception of climate change and the SARS-CoV-2 pandemic. Finally, we wanted to investigate the perceived cost for the risks considered (SARS-CoV-2 pandemic or climate change). Indeed, as for every risk, there are some costs to face so we decided to investigate if there is a difference in the perception of the costs (i.e. economic, temporal, societal, personal costs) in relation to the risk considered. In literature, there is evidence that people tend to delay actions to mitigate future risk whether they require a concrete present cost (Milinski et al., 2008; Weber, 2010).

Hypothesis 1a: Risk perception should depend on the type of risk (climate change vs. SARS-CoV-2 pandemic), specifically: the SARS-CoV-2 pandemic's risk perception should be higher than the climate change's risk.

Hypothesis 1b: In line with the previous hypothesis, cooperative behaviors should also depend on the type of risk (climate change vs. SARS-CoV-2 pandemic), specifically: in the SARS-CoV-2 pandemic condition, cooperative behaviors should be higher than in the climate change condition.

Then, we expected that a higher level of risk perception would lead to a higher level of cooperation. We based this hypothetical relation on the risk-as-feeling model; thus, a higher visceral response to risk and a higher emotional response to risk leads to a higher willingness to act to reduce the perceived risk (Loewestein et al., 2001; Slovic et al., 2004). We measured participants' level of cooperation through two social dilemmas - the Public Good Games and the Intergenerational Good Games- where the amount of money ideally shared corresponds to the level of cooperation.

Hypothesis 2: An increase in risk perception should lead people to be more cooperative.

Moreover, in literature, there is evidence supporting the role of time-preference in decision making (Chapman, 1996; Frederick et al., 2002). Indeed, people tend to discount future costs for the benefit of the present despite the objective or statistical assessment of the risk (Milinski et al., 2008; Slovic et al., 2002, 2007). This is also related to the difficulty representing the future and thus the lack of affective imagery (Trope & Liberman, 2003; Weber, 2006, 2010). However, people make decisions differently in relation to the present and the future, especially in the context of climate change (Jacquet et al., 2013). Therefore, we assumed a mediated relationship between time discounting, perception of costs and benefits, and cooperative behaviors (see Figure 5).

Hypothesis 3: Further, the extent to which respondents will show cooperative behaviors should depend on their level of time discounting whose effects should be mediated by people's perception of the costs and benefits of cooperating.

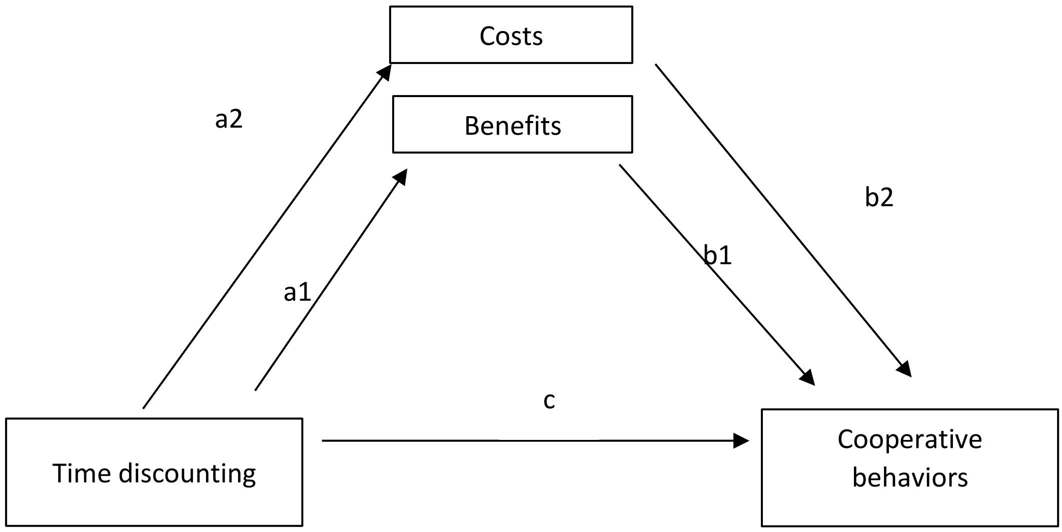



**Figure 5.** Mediation model of Hypothesis 3.

Another important factor to consider is affect, central in risk perception. Indeed, in this study, we compared two different risks, and relying on the risk-as-feeling response to risks we already know that people response to risk relying on their visceral and instinctive system (Loewestein et al., 2001; Slovic et al., 2004). In addition, people are subjected to the affect heuristic, thus the valence of affect associated with a risk leads to a perception of the risk of the same type (Slovic & al., 2002, 2004; Slovic & Peters, 2006). Moreover, to the extent of our knowledge, little is known about the affect associated with the exponential growth of risks. Thus, we hypothesized as follows:

Hypothesis 4a: For each type of risk, an increase in negative affect induced by exponential growth should lead to an increase in risk perception.

People do not respond only to instincts and emotions when they face risks, but they also have some objective information about them. In the SARS-CoV-2 pandemic literature, it has been reported the positive direct relation between objective information about this global virus and the increment of risk perception (He et al., 2021; Rubaltelli et al., 2021; Schneider et al., 2021A). Not all scholars are in line with the latter view, indeed Zhong et al. (2021) supported a negative correlation between the scientific knowledge of the SARS-CoV-2 pandemic and risk perception. On the contrary, what finds an agreement in literature is that risk perception and cooperative behaviors in a SARS-CoV-2 pandemic context are linked by a positive direct relation, thus at the increase of the first the latter increases too (Caserotti et al., 2022). To the extent of our knowledge, it has not been investigated the role of risk perception as the mediator in the relationship between scientific knowledge and cooperative behaviors. Moreover, it has been demonstrated that there is a correlation between the level of perceived scientific agreement on climate change and increase risk perception, leading to major involvement in public action (van der Linden et al., 2015). Thus, we hypothesized that the level of scientific knowledge (a) could have an effect on cooperative behaviors (c) through a mediated relation (b; see Figure 6). In particular, we expected that increasing scientific knowledge would be associated with increased risk perception in both domains (SARS-CoV-2 pandemic and climate change). Hence, risk perception would be the process through which scientific knowledge should lead to more cooperative behaviors as a way to reduce the perception of risk.

Hypothesis 5: Respondents' level of scientific knowledge should lead them to perceive higher risk and to engage in more cooperative behaviors. Thus, we expect the risk perception to mediate the relationship between scientific knowledge and cooperative behaviors.

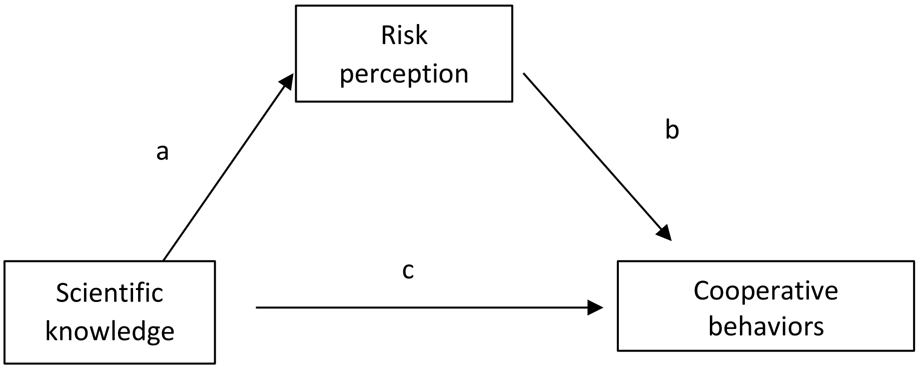



**Figure 6.** Mediation model for Hypothesis 5.

Furthermore, exploratory analyses will be run for the following dimensions: engagement, warm glow, and motivation to act. The goal of these analyses will be to understand the relationships among these dimensions and between these dimensions and other variables measured in the experiment. Our design will also control group differences in trait EI, time discounting, and socio-demographic characteristics.

## 4. Method.

### 4.1 Pre-tests.

To better develop the main study and to increase its validity, some variables have been pre-tested through two pre-tests (pre-test A and pre-test B) that were completed by two independent samples of subjects. Both the pre-tests were implemented on Qualtrics. Participants were asked for their informed consent before and after completing the survey.

Participants were contacted through social media (such as Instagram, Facebook, WhatsApp, etc.). In total, 165 participants have been recruited: in the pre-test A we collected 83 responses (mean age = 30.23, SD = 13.84; 50 females), while in the pre-test B we collected 82 responses (mean age = 36, SD = 15.61; 50 females).

The structure of both pre-tests was similar. Indeed, both of them were organized into two conditions: the climate change condition and the SARS-CoV-2 condition. Each participant was presented with both conditions, and the order was randomized between participants. Then, for each condition, a set of questions were presented to investigate the psychological dimension of the risk investigated (i.e., climate change or SARS-CoV-2 pandemic). The order of these questions was randomized between participants. Finally, a further section investigated if participants had any previous experiences with climate change and the SARS-CoV-2 pandemic.

The difference between the two pre-tests laid mainly in the content of the dimensions investigated. In particular, pre-test A assessed the psychological dimensions of the two risks (i.e., climate change and SARS-CoV-2 pandemic), while pre-test B explored a range of questions measuring people's scientific knowledge about the two risks.

In pre-test A, the psychological perception of the two types of risks has been assessed through these dimensions: engagement (divided into six subcategories: active speech, passive speech, importance to act, effort to act, responsibility, relevance, and morality); uncertainty; belief-scientific consensus; risk perception (divided into: likelihood of risk, characteristics of risk, temporal scale, spatial scale, and costs for the prevention of the risk); warm glow; behavior motivation; and actual behavior. All these dimensions have been tested for both risks and adapting the questions accordingly. At the end of the survey, participants reported their demographic information: gender, age, income, educational level, political orientation, and religiosity.

Pre-test B investigated participants' scientific knowledge about the two risks. Specifically, the scientific knowledge was investigated according to the accuracy in responding to scientific questions about the risks and the participants' perception of how difficult the questions were. As previously, all the questions were randomized. So, half of the participants saw all the questions of the condition of climate change first followed by all the questions of the SARS-CoV-2 condition, while the other half of the sample saw the two conditions in the opposite order.

Once the data have been collected, they have been analyzed with the software R (R Core Development Team, 2020). For pre-test A, an Exploratory Factor Analysis (EFA) was conducted to identify the variables, and so the questions, to assess the factor structure of the different dimensions within each risk (i.e., climate change vs. SARS-CoV-2 pandemic). We preferred to use this analytical technique because we aimed to divide all the variables previously described into the least number of factors possible. The number of factors was determined based on the Eigen value. Once the factors were established, we computed the Cronbach's alpha in order to verify the internal consistency for each of them. The criterion of selection for each item was the highest internal consistency measured through Cronbach's alpha. All the questions with low Cronbach's alpha in all the factors have been excluded from the main study.

For pre-test B, we opted for another type of analysis. Relying on the structure of this pre-test, we have analyzed the response accuracy for each given answer. Thus, for each risk, we have categorized the perceived difficulty of the questions into quintiles (0-20, 21-40, 41-60, 61-80, 81-100), and we have verified with chi-square analysis which questions belonged to each quintile. Furthermore, we wanted to ensure that the questions were as similar as possible, so we performed a series of t-test analyses. In the end, we selected the questions that were similar both in mean (M) and standard deviation (SD). In particular, from each condition (climate change vs. SARS-CoV-2 pandemic), we extrapolated a pair of questions from each middle quantile (41-60, 61-80). While we decided to consider just one question for the 21-40 quantile and one for the highest (81-100) quantile. Indeed, in the pre-test B in addition to the knowledge questions there were questions about the perceived difficulty of questions themselves, thus relying on the analysis we decided to consider just one question in the quantile 21-40 and one in the quantile 81-100 because they were perceived, respectively, as too simple or too complex. We did not consider any questions from the lowest quantile in absolute (0-21), because there were no questions in the SARS-CoV-2 pandemic condition to make a comparison with the climate change condition. At the end of our analysis, the questions that we selected for the study were six from the climate change condition and six from the SARS-Cov-2 pandemic condition.

### 4.2 Power analysis.

To estimate the minimum sample size required for the experiment we ran a power analysis. (Tomczak et al., 2014). The power analysis was implemented in R (R Core Development Team, 2020) using the package "pwr" (Champely et al., 2017), and we have proceeded in two fashions. Using the formula for the power calculation for the balanced one-way analysis of variance, we selected an effect size (EF) of at least .50 considered medium using Cohen's (1998) criteria. At first, we analyzed the sample's possible size hypnotizing a power analysis of 0.80 with a significance level of 0.5. The projected sample size that we would need was 45 for each group. Then, we worked in another way because our initial idea was to have a sample of 100 people for each group. So, we set the number of observations per group at 100, the effect size at 0.25 with a significance level of 0.5, the resulting power was .99. Therefore, with 100 participants for each group, we should be able to control expected attrition and mediating and moderating factors.

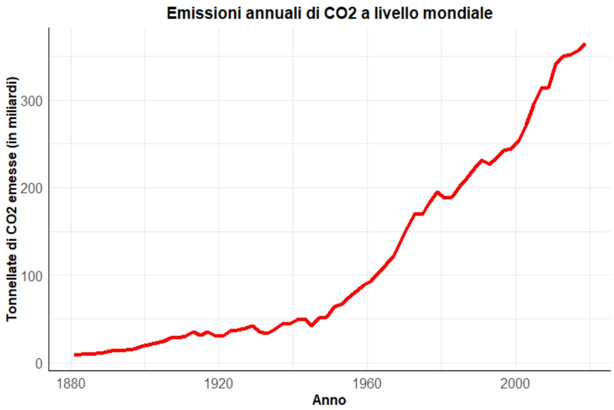
### 4.3 Participants.

Relying on the result of the power analysis, 429 participants (mean age = 28.76, SD = 10.7; 276 females) took part in the main study. The survey was implemented on Qualtrics. Data collection has been done by sending messages through social media (i.e. WhatsApp, Facebook, Instagram). Participants were randomly assigned to one of the four conditions of the study. Since the experimental design was fully between-subjects, the participants were presented with either one of the "climate change" conditions (experimental or control), or with one of the "SARS-CoV-2 pandemic" conditions (experimental or control).

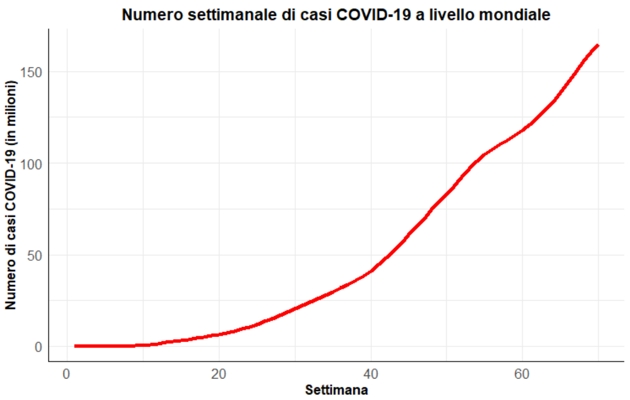
The only criterion of selection was to be adults. As an exclusion criterion, we set the time participants spent on the experimental manipulation (an image accompanied by a scenario). All participants whose time on this page was 3SD above the average time were excluded. We decided to add this time criterion because it was an online survey and participants' effort to do the task in a proper way was more difficult to control (i.e., they could get distracted, be in a noisy room, be talking to someone, and so on).

### 4.4 Experimental design.

The experimental design was 2 (risk: climate change vs. SARS-CoV-2) x 2 (condition: experimental-real data vs. control-data swapped between the two risks). In each of the four, between-subject conditions, participants saw a chart related to the risk considered. Data for the charts were taken from Our World in Data (www.OurWorldinData.org) and were paired with a short scenario created ad hoc. The chart for the "climate change" experimental condition showed the tons of carbon dioxide ($CO_2$) emitted per million globally each year from 1881 to 2019 (see Figure 7a).




a




b

**Figure 7.** (a) Chart of "climate change" condition showing the tons of carbon dioxide ($CO_2$) emitted per million globally each year from 1881 to 2021. (b) Chart of the "SARS-CoV-2-pandemic" condition showing the weekly average of new cases daily of SARS-CoV-2 in millions registered globally from January 22, 2020, to May 19, 2020.

While the chart for the "SARS-CoV-2 pandemic" condition showed the weekly average of new cases daily of SARS-CoV-2 in millions registered globally from January 22, 2020, to May 19, 2020 (see Figure 7b). Even in this experimental condition, the graph is followed by a short ad hoc description similar to the "climate change condition."

Finally, the two-control condition mixed the scenarios and charts so that we could control the impact that each had on people's answers. Therefore, a condition presented the climate change scenario together with the chart depicting the SARS-CoV-2 cases (the labels were changed accordingly; see Figure 1 in Appendix section A) and another condition presented the SARS-CoV-2 scenario together with the chart depicting $Co_2$ emissions (again with the labels changed accordingly; see Figure 2 in Appendix section A).

## 4.5 Procedure

### 4.5.1 The mental images task.

First, participants were presented with the manipulation; subsequently, they were asked to complete mental images tasks. The task is divided into two stages. In the first stage, the participant had to write down at least one word (and up to three) that came to their mind while looking at the charts. Then they are asked to rate the valence of each of the words they have written down using a scale between -2 ("Absolute negative") to +2 ("Absolute positive"). In the analyses, affect will be considered as both the first mental image and the mean of the three images.

### 4.5.2 Survey originated from pre-test A.

After this task, the questionnaire presented participants with the variables selected in pre-test A: risk perception, warm glow, motivation to act, and engagement. Risk perception was one of the primary dependent variables, and it was measured asking participants to rate of likely, severe, controllable, visible, and fatal was the risk they were presented with (climate change or SARS-CoV-2 pandemic). Each of these five questions was answered on a 0 (minimum) to 100 (maximum) slider scale. In addition, we measured the spatial scale and the temporal scale of the specific risk through two different sliders ranging from 0 (few weeks/local effect) to 100 (decades/global effect). Additional questions, measured people's perception of different prevention's costs associated to the risk taken into consideration (climate change or SARS-CoV-2 pandemic): economic, temporal, social, and personal. Answers were given on a slider going from 0 ("Not at all") to 100 ("Extremely") in 10 points increments.

The warm glow was measured asking participants to rate their emotional reactions (such as good, satisfied, proud, respectable, etc.) when thinking how they would feel enacting a behavior aimed at preventing behaving to prevent the risk considered (climate change vs. SARS-CoV-2 pandemic). For each emotion, people provided a rating of how they felt on a slider scale ranging from 0 ("Not at all") to 100 ("Extremely") in 10 points increments.

The motivation to act questions asked participants their willingness to make sacrifices to reduce the risk under consideration (from 0 = "Not at all" to 100 = "Extremely") while their engagement to the risk was measured through different questions: we asked participants how often they talk about the risk with their families and friends or have heard family and friends talk about it (from 1 = "almost never" to 5 = "almost every day"). Then, we asked participants to rate the importance of acting to contain climate change or the SARS-CoV-2 pandemic, depending on the condition. This question was followed by another one measuring the extent to which they act to fight the risk considered. These last two questions have been investigated personally, on a friendship level, and a familiar level. Participants answered these scales on a 5-point scale ranging from 1 ("Not at all") to 5 ("Extremely").

Finally, we asked them to rate the extent to which they agreed with 5 statements related to the personal importance of the risk they were presented with. Answers were provided on a slider scale ranging from 0 ("Completely disagree") to 100 ("Completely agree"). Examples of the statements are the following: "For me, the phenomenon of climate change [SARS-CoV-2 pandemic] is really important", "I am morally outraged by myself if I don't help reducing the effects of climate change [SARS-CoV-2 pandemic]" (alternative condition in square brackets).

### 4.5.3 Public Goods Games (PGG) and Intergenerational Goods Games (IGG)

After this first part of the survey, participants had to complete two games: the Public Goods Game (PGG; Marwell & Ames, 1979) and the Intergenerational Goods Game (IGG; Hauser et al., 2014). Both games are used to measure individuals' level of cooperation through scenarios presenting a social dilemma. In the PGG both the cost and the benefit are perceived in the present, while in the IGG the cost is perceived in the present but the benefit of the decision will be perceived in the future. In both these games, the cost is perceived by the participant, while the benefit is perceived by the participant in the PGG but by someone else in the future in the IGG. Therefore, in the PGG, people can cooperate to maximize the benefits for the group or free ride maximizing their own benefits themselves. Whereas, in the IGG, people can cooperate to maximize the benefits for someone else in the future or free ride and maximize their benefits in the present. In both these social dilemmas, the free riders are the group members who are selfish and maximize their own profit without contributing to the common cost (i.e. pay for public service). In this way, they benefit both from other members' contributions and from saving their money shares (Marwell & Ames, 1979). Indeed, regardless of the contribution participants give, the accumulated amount is equally shared among all the community members. Using these features, we created a scenario for the PGG and a scenario for the IGG and, in both games, participants used a slider ranging from 0€ to 100€ with increments of 5€ to select the amount of money they were willing to contribute to a common cause. They were free to choose the amount they wanted to donate. In both the good games we used the one-shot version, so people had to fill the scenarios just once. After each game, participants provided ratings on three dimensions (costs, benefits, and efficacy of their economic contribution) in relation to the decision just made. Answers to these questions were provided on a 7-point scale ranging from 1 (“Not costly/Not beneficial at all/Strongly disagree”) to 7 (“Very costly/Very beneficial/Strongly agree”).

### 4.5.4 Knowledge questions from pre-test B.

Finally, we added the same questions previously used in the pre-test B taken from the NASA website (https://climate.nasa.gov/quizzes/air-we-breathe-quiz/). For each multiple-choice question, there was only one correct answer. Furthermore, there were six questions for each condition (climate change vs. SARS-CoV-2 pandemic). Some examples that were in our survey are the ones following: “How far can air pollution move away from its source?”, “Which of the following gases does not trap heat?”, “What does COVID-19 attach to when it enters the human body?”, “What is a fomite?”.

### 4.5.5 Scales

Another survey’s step was to fill the Trait Emotional Intelligence Questionnaire-Short Form (TEIQue-SF; Petrides, 2009) and the Convex Time Budget (CTB; Andreoni et al., 2015). In particular, the former’s aim was to measure the affect through participants’ trait emotional intelligence, so the TEIQue-SF was structured with 30 items regarding the emotional sphere. In particular it had a hierarchical structure and investigated the 15 facets (i.e. trait empathy, emotion perception, emotion expression, relationships, emotion management, assertiveness, social awareness, self-esteem, trait optimism, trait happiness, emotion regulation, impulsiveness (low), stress management, adaptability, self-motivation) of the TEIQue including two items for each of them, thus it was possible to scores the four trait EI factors (i.e. emotionality, sociability, self-control, well-being; Petrides, 2019). Participants could express their levels of agreement with the presented statements thanks to a scale going from 1 (“Completely disagree”) to 7 (“Completely agree”).

Convex Time Budget (CTB) was another scale that participants had to fill. The CTB purpose is to investigate the curvature of the utility function relying on time preference (Andreoni et al., 2015). People tend to show time discounting when comparing costs and benefits of different times. It is not related to the economic field but also to psychology, risk perception, and any possible scenario where it is possible to make a trade-off between present and future. Referring to our study we used the CTB approach to measure the temporal discounting in SARS-CoV-2 pandemic and climate change. In the CTB approach, participants had the possibility to allocate an amount of money immediately (today) or in the next future (5 weeks). The deletion of the reward determined the rate of interest along a convex budget set of scenarios (Andreoni & Sprenger, 2012). Therefore, the scenarios in the convex time budget scale were binary choices of present versus future rewards of money with a constant proportion between them (Andreoni et al., 2015). This constant portion corresponded to the gross interest rate (P) which was given by the ratio between the "in 5 weeks" budget (y) and the "today" budget" (x), thus P = $\frac{y}{x}$ (Andreoni et al., 2015). Therefore, in our study, the maximum amount achivable in each bynary choice was between 0€ and 20€ following along a convex budget set with a binding interest rate (P; see Appendix for all scenarios B).

### 4.5.6 The exponential problems and individual differences.

Participants had to answer two exponential problems to prove that they had understood the exponential growth of the graphs. Both exponential problems had a multiple-choice structure with one correct solution, even in this case. The first exponential problem was about the growth of a Ninfea, and the second one was about the growth of a population of three specimens of a bacteria.

At the end of the survey, we maintained the same general socio-demographic questions we used in the pre-tests (age, income, educational level, etc.).

## 5. Results.

### 5.1 Preliminary analysis.

First of all, we ran a preliminary analysis to assess whether there was a difference between the experimental and control conditions. Indeed, our goal was to compare the two risks (SARS-CoV-2 pandemic vs. climate change), combining the two conditions in which we proposed the charts with the actual data for each risk (experimental condition) or we swapped the charts for the two risks (control conditions). First, we assessed whether there were any statistical differences between the two conditions (experimental vs. control) of each risk (climate change and SARS-CoV-2 pandemic) along the risk perception variable, thus we ran a t-test for each dimension of risk perception (i.e. temporal scale, spatial scale, the likelihood of being impacted by risk, characteristics of the risk, and cost of the risk). These results are shown in Table 1, for climate change, and in Table 2 for the SARS-CoV-2 pandemic. Thus, we merged the conditions (experimental and control) in a unique condition for each risk (climate change and SARS-CoV-2 pandemic).

| | *t* (221) | *p* | Experimental cond. M (SD) | Control cond. M (SD) |
|---|---|---|---|---|
| RP in climate change conditions | | | | |
| Temporal scale (RP) | 1.13 | 0.26 | 79.78 (23.29) | 76.32 (22.35) |
| Spatial scale (RP) | -2.64 | 0.008 | 85.74 (19.64) | 92.19 (16.45) |
| Likelihood of risk (RP) | -0.60 | 0.55 | 73.84 (18.69) | 75.37 (16.69) |
| Characteristics (RP) | -1.75 | 0.08 | 85.70 (14.47) | 88.84 (12.04) |
| Costs (RP) | -0.76 | 0.45 | 57.81 (20.64) | 59.88 (20.14) |

**Table 1.** Results of the t-tests between climate change conditions (experimental vs. control).

| | *t* (204) | *p* | Experimental cond. M (SD) | Control cond. M (SD) |
|---|---|---|---|---|
| RP in SARS-CoV-2 pandemic conditions | | | | |
| Temporal scale (RP) | -0.48 | 0.63 | 37.20 (21.46) | 38.84 (26.66) |
| Spatial scale (RP) | -1.03 | 0.31 | 88.58 (19.89) | 91.36 (18.97) |
| Likelihood of risk (RP) | 0.09 | 0.93 | 47.74 (16.90) | 47.52 (18.86) |
| Characteristics (RP) | -0.38 | 0.71 | 60.83 (18.00) | 61.80 (18.69) |
| Costs (RP) | 0.30 | 0.76 | 63.95 (18.23) | 63.09 (22.50) |

**Table 2.** Results of the t-test between the SARS-CoV-2 pandemic conditions (experimental vs. control).

Second, the same analysis was used to measure differences between the conditions of each risk (climate change and SARS-CoV-2 pandemic) and the amount shared in cooperative game (PGG vs. IGG). These results are showed in Table 3, for the PGG, and Table 4, for IGG.

| | *t* (221) | *p* | Experimental cond. M (SD) | Control cond. M (SD) |
|---|---|---|---|---|
| PGG amount | | | | |
| Climate change | -1.18 | 0.24 | 71.36 (28.24) | 75.81 (28.00) |
| SARS-CoV-2 pandemic | -0.53 | 0.60 | 66.80 (31.85) | 69.20 (33.53) |

**Table 3.** Results of the t-tests between the PGG amount in the climate change and SARS-CoV-2 pandemic conditions (experimental vs. control).

| | *t* (221) | *p* | Experimental cond. M (SD) | Control cond. M (SD) |
|---|---|---|---|---|
| IGG amount | | | | |
| Climate change | -0.79 | 0.43 | 68.98 (28.20) | 72.10 (30.78) |
| SARS-CoV-2 pandemic | -0.39 | 0.69 | 62.25 (33.47) | 64.10 (33.92) |

**Table 4.** Results of the t-tests between the IGG amount in the climate change and SARS-CoV-2 pandemic conditions (experimental vs. control).

Finally, we combined the PGG and the IGG for the risks without considering the survey's conditions. After these preliminary analyses, we combined all the variables considered in our study relying only on the risk (SARS-CoV-2 pandemic vs. climate change) and analyzed all the hypotheses considered.

### 5.2 The risk perception changes depending on the risk considered.

To analyze Hypothesis 1a, we compared the risk perception associated with the two types of risk (SARS-CoV-2 pandemic vs. climate change). Since we were assessing the risk perception, a multi-factor variable, we ran different t-tests for each variable, always comparing them across type of risk (climate change, SARS-CoV-2 pandemic). On the temporal scale, a statistically significant difference emerged with a lower score for SARS-CoV-2 pandemic than for climate change. On the spatial scale, the difference was not significant. Regarding the likelihood of being impacted by the specific risk, the results revealed a statistical difference with climate change associated with a higher likelihood than SARS-CoV-2. Similarly, in terms of risk characteristics, climate change was judged more dangerous, with severe and fatal consequences, controllable, and with visible effects than SARS-CoV-2. Finally, the cost of reducing the risk associated to climate change was judged lower than the cost of fighting SARS-CoV-2. All these results are showed in Table 5. These comparisons show that the risk of climate change is perceived as higher than that of SARS-CoV-2 on several of the dimensions we measured. These findings do not support Hypothesis 1a, in fact they downright contradict it.

| | *t* (427) | *p* | Climate change M (SD) | SARS-CoV-2 pandemic M (SD) |
|---|---|---|---|---|
| VD: Risk perception (RP) | | | | |
| Temporal scale (RP) | 16.75 | <0.001 | 78.15 (22.86) | 38.04 (24.23) |
| Spatial scale (RP) | -0.67 | 0.50 | 88.78 (18.45) | 90.01 (19.42) |
| Likelihood of risk (RP) | 15.02 | <0.001 | 74.56 (19.14) | 47.63 (17.89) |
| Characteristics of risk (RP) | 16.75 | <0.001 | 87.18 (13.44) | 61.33 (18.32) |
| Costs (RP) | -2.39 | 0.02 | 58.78 (20.39) | 63.51 (20.49) |

**Table 5.** Results of the t-tests ran to analyse Hypothesis 1a for whom we supposed that the risk perception (RP), declined in all its factors, would be higher for SARS-CoV-2 pandemic than for climate change.

### 5.3 The type of risk modulates the level of cooperative behaviors.

Hypothesis 1b was analyzed using t-tests as well. The average amounts contributed in the PPG and IGG were compared across types of risk in two separate analyses. For the PGG, no statistical difference emerged. For the IGG, the analysis showed a significant effect, in particular people contributed more to future generations in the climate change condition than in the SARS-CoV-2 condition. These results are showed in details in Table 6. Neither of these results supported Hypothesis 1b.

| | *t* (427) | *p* | Climate change M (SD) | SARS-CoV-2 pandemic M (SD) |
|---|---|---|---|---|
| VD: Game | | | | |
| PGG (amount) | 1.85 | 0.07 | 73.45 (28.16) | 68.03 (32.62) |
| IGG (amount) | 2.38 | 0.02 | 70.45 (29.42) | 63.20 (33.63) |

**Table 6.** Results of the t-tests ran to analyse Hypothesis 1b for whom we supposed that the cooperative behaviors (PGG vs. IGG) would be higher in the SARS-CoV-2 pandemic condition than in climate change condition.

### 5.4 The relationship between risk perception and cooperative behaviors.

To test Hypothesis 2, we ran a linear multilevel regression model with risk perception, type of social dilemma (PGG vs. IGG), and their interaction as predictors of cooperative behaviors (amount contributed) while controlling for the random effect of the participant. Since the different dimensions of risk perception were highly correlated, we ran a different model for each dimension. Table 7 reports data for the models in which an interaction between risk perception dimension and type of dilemma was significant; all other results are reported in the text below. For the temporal dimension, the analysis revealed only a main effect of the social dilemma ($B$ = -.005; $SE$ = .002; $t$= -2.66; $p$ = .008). People were more cooperative, so they shared a higher amount of money in the PGG than in the IGG ($B$= -.005).

In the second mixed model we used as predictor the spatial scale of risk and found only a main effect of risk perception ($B$ = 0.25; $SE$ = 0.11; $t$ = 2.32 $p$ = 0.02). This finding suggests that when the risk is perceived as closer people are more likely to contribute more in the two games.

As for the likelihood of being impacted by the risk, we found a main effect of the type of game ($B$ = -9.33, $p$ = 0.001) and an interaction between the type of game (PGG vs. IGG) and the risk perception (*B* = 0.09; *p* = 0.04; see Table 7). When the likelihood of the risk was perceived as high people contributed the maximum amount in both games, whereas when the score on this dimension of risk perception was low people contributed more in the PGG (*B* = 0.16; *SE* = 0.06; *t* = 2.50; *p* = 0.01; see Figure 8) than in the IGG (*B* = 0.25; *SE* = 0.06; *t* = 3.86; *p* = 0.00; see Figure 8).

| | *B* | *SE* | *T* | *P* |
|---|---|---|---|---|
| (Intercept) | 70.18 | 5.84 | 12.01 | < .001 |
| Likelihood of risk (RP) | 0.07 | 0.09 | 0.83 | 0.41 |
| Game (PGG vs. IGG) | -9.33 | 2.83 | -3.30 | 0.001 |
| Interaction between Game and likelihood of risk | 0.09 | 0.04 | 2.06 | 0.04 |

**Table 7.** Fixed effects of the third mixed model among the risk perception of the likelihood of being impacted by a risk (Likelihood of risk), the game (PGG vs. IGG), and their interaction.

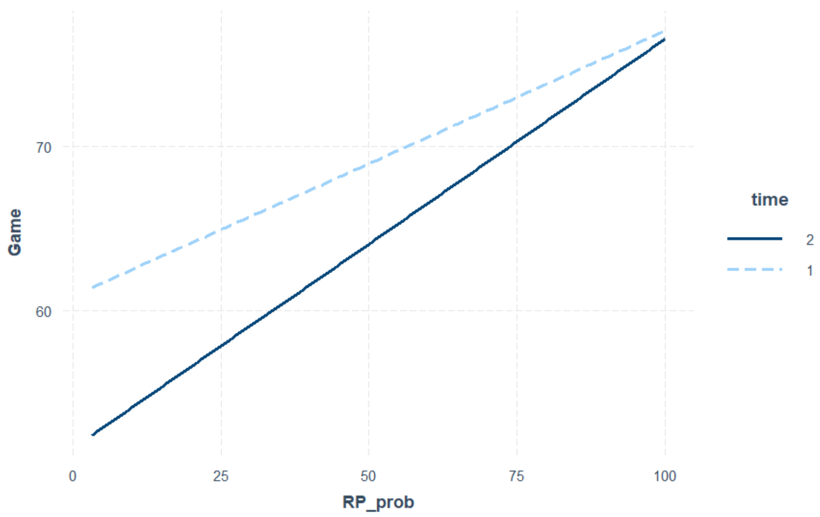



**Figure 8.** Slope-analysis for the interaction between the likelihood of being impacted by a risk (RP_prob) and the type of game (time 1 = PGG, time 2 = IGG). There is a positive linear correlation between the two factors, but the IGG (time 2) is always sloper than PGG (time 1).

The type of game (PGG vs. IGG) had a significant effect on the level of cooperation considering the model with the characteristics of risks ($B$ = -8.87; $SE$ = 3.73; $t$ = -2.38; $p$ = 0.02). In particular, people collaborated less in the IGG ($B$ = -8.87). On the contrary, in the model with costs did not emerge any statistically significant results.

### 5.5 Cooperative behaviors should depend on the level of time discounting, whose effects should be mediated by the perception of costs and benefits of cooperation.

To analyze Hypothesis 3, we relied on the responses given to the CTB. We added together the answers to each item, thus creating an index with a maximum value of 36. Then, we calculated the total average for our sample, which was high (mean= 26,53), revealing that our sample generally is not subjected to temporal discounting. Then we ran several mediation models to test the relationship between time discounting and cooperative behaviors while adding to the models the costs and benefits factors. Here we will report just the two mediation models with all the variables included, the former considering the PGG and the latter considering the IGG. Thus, the only difference between the two mediation models is the type of game, since both considered the type of risks (SARS-CoV-2 pandemic vs. climate change), costs, and benefits. In the mediation model with the PGG the results revealed that there was only a statistically significant effect of the costs ($B$= -4.47; $p$=0.000) and benefits ($B$= 10.55; $p$=0.000) on the cooperative behaviors (PGG). In particular, as the perceived benefits increased the amount contributed increased too, while as perceived costs increased the amount contributed decreased (see Table 8).

| | *B* | *SE* | *Z* | *P* |
|---|---|---|---|---|
| VD: Game (PGG) | | | | |
| Temporal discounting (c1) | 0.18 | 0.16 | 1.11 | 0.27 |
| Benefits (b1) | 10.55 | 0.96 | 11.01 | 0.000 |
| Costs (b2) | -4.47 | 0.81 | -5.51 | 0.000 |
| M: Benefits | | | | |
| Temporal discounting (a1) | 0.004 | 0.006 | 0.59 | 0.55 |
| M: Costs | | | | |
| Temporal discounting (a1) | 0.004 | 0.006 | 0.59 | 0.55 |
| Indirect path 1 | 0.04 | 0.06 | 0.59 | 0.56 |
| Indirect path 2 | -0.02 | 0.03 | -0.59 | 0.56 |
| Total effect | 0.20 | 0.16 | 1.21 | 0.22 |

**Table 8.** Regressions and defined parameters of the mediated model of Hypothesis 3 considering the PGG.

Moreover, we analyzed whether the direct relation between temporal discounting and PGG was statistically significant or not. Even in this case, the result showed that there was no significant relation (*B*= 0.30; *SE* = 0.19; *z* = 1.63; *p*= 0.11).

We proceeded in the same fashion for the IGG. Therefore, we analyzed the mediation model considering only this game and we discovered that there is no mediation effect but only a main effect of costs (*B*= -5.38; *p*= 0.000) and benefits (*B*= 10.20; *p*= 0.000) on IGG (see Table 9). An increment in the benefits led to a higher amount of money shared in the IGG.

| | *B* | *SE* | *Z* | *P* |
|---|---|---|---|---|
| VD: Game (IGG) | | | | |
| Temporal discounting (c1) | 0.11 | 0.16 | 0.69 | 0.49 |
| Benefits (b1) | 10.20 | 0.92 | 11.11 | 0.000 |
| Costs (b2) | -5.38 | 0.77 | -6.96 | 0.000 |
| M: Benefits | | | | |
| Temporal discounting (a1) | 0.006 | 0.006 | 0.90 | 0.37 |
| M: Costs | | | | |
| Temporal discounting (a1) | 0.006 | 0.006 | 0.90 | 0.37 |
| Indirect path 1 | 0.06 | 0.07 | 0.10 | 0.37 |
| Indirect path 2 | -0.03 | 0.03 | -0.89 | 0.37 |
| Total effect | 0.14 | 0.16 | 0.85 | 0.40 |

**Table 9.** Regressions and defined parameters of the mediated model of Hypothesis 3 considering the IGG.

Finally, we analyzed the direct relation between the temporal discounting and the IGG, but the result was not significant (*B*= 0.22; *SE* = 0.19; *z* = 1.12; *p*= 0.26).

### 5.6 How negative affect impacts risk perception relying on the exponential growth of the risk.

Hypothesis 4a states that ‘for each type of risk, an increase in negative affect induced by exponential growth should lead to an increase in risk perception.’ Thus, we analyzed the correlation between affect and risk perception for each type of risk. In particular, the affect was operationalized as both the valence of the first mental image and the average valence of the three mental images. The results highlighted a high correlation between mental images in both the risk analyzed (SARS-CoV-2 pandemic and climate change). In particular, Figure 9 shows the correlations between the mental images and the different levels of risk perception for the SARS-CoV-2 pandemic condition, while Figure 10 shows the same correlations for the climate change. In the SARS-CoV-2 pandemic condition, the correlation between the valence of the first mental images and the average valence mental images is statistically significant ($r$ = 0.78) following a positive direct relation between the two factors considered. Thus, as the former increase so do the latter. Even the correlation between the likelihood of being impacted by a risk and risk characteristics was a direct positive correlation ($r$ = 0.39), even if it was less slope than the previous one. Moreover, there is a low positive correlation ($r$ = 0.14) between the spatial scale and the risk’s costs. Even from the graphic it is possible to see that the correlation is not so strong, because the curve is almost flat.

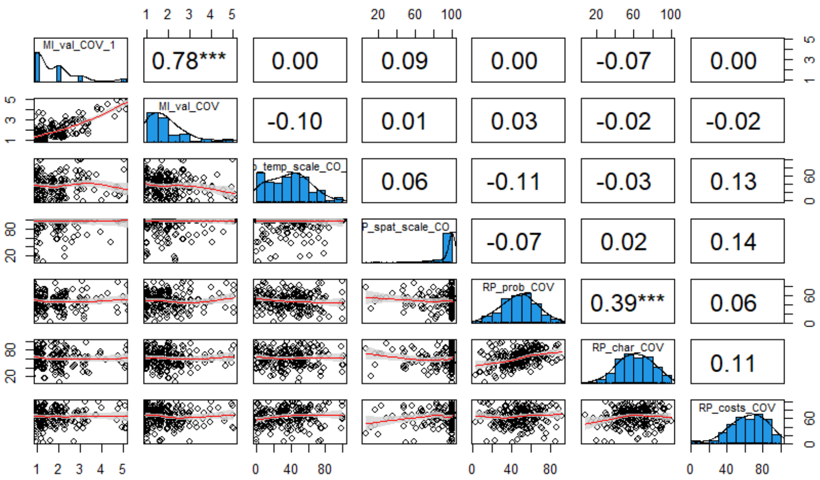



**Figure 9.** Correlations between the valence of mental images and the different risk perception variables in the SARS-CoV-2 pandemic condition.

In the climate change condition, the results showed a high positive correlation between the valence of the first mental image and the average valence of mental images ($r = 0.72$). On the contrary, the average valence of mental images has no correlation with risk perception levels. Considering the temporal scale, it had a little positive correlation with the risk's costs ($r = 0.14$) and it is described by an almost flat curve with the highest concentration of participants' answers in the higher values. Moreover, the spatial scale had a positive correlation between the likelihood of being impacted by a risk ($r = 0.18$), where the curve showed a not so strong correlation as it is almost flat. In addition, the spatial scale had a positive correlation with the risk characteristics too ($r = 0.19$) and the curve is slooper than the one describing the correlation between the spatial scale and the likelihood of being impacted by a risk. In the former correlation, the curve showed a positive relationship which is not so strong, indeed it is almost horizontal. The latter correlation referred to a positive correlation too but was higher than the former one. What emerged, is a strong correlation between the likelihood of being impacted by risk and the risk's characteristics, with a significant statistical correlation of $r = 0.49$. It is described by a positive direct relationship between the factors. The likelihood of being impacted by risk is positive correlated with risk's costs too, but this correlation is low (*r*= 0.17) and the curve is less steep compared to the one just described. Finally, risk characteristics and risk's costs factors of risk perception are positively correlated too, but their correlation is not statistically so significant (*r*= 0.15) and the curve is almost flat.

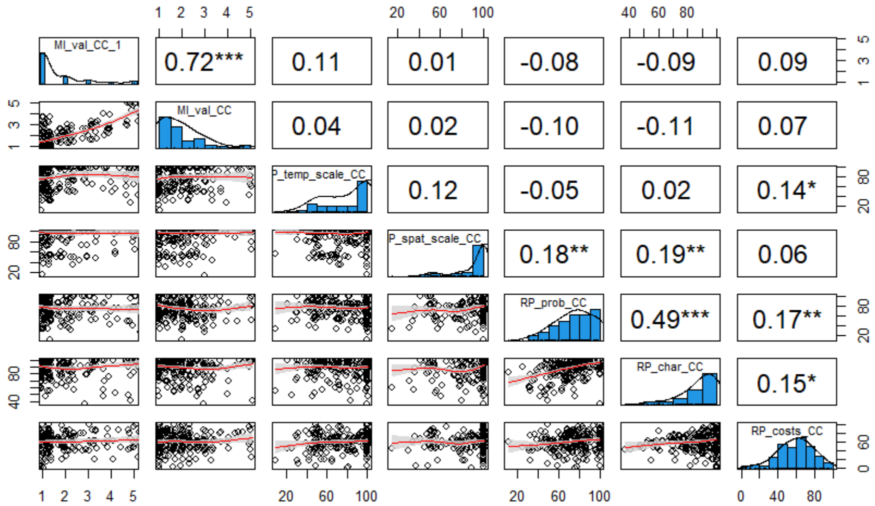



**Figure 10.** Correlations between valence of mental images and the different risk perception levels in the climate change condition.

What is really interesting is that, for both risks (SARS-CoV-2 pandemic and climate change) the valence of mental images, taken as the average of the three mental images presented or as only the first mental image, is not correlated or had a negative correlation with all the variables of risk perception (see Figure 9 and Figure 10). These results go against our hypothesis.

### 5.7 The level of scientific knowledge about the risk leads to a higher risk perception that mediates cooperative behaviors.

The last hypothesis that we tested was Hypothesis 5. Our aim was to investigate whether the relationship between the scientific knowledge of risk and cooperative behaviors was mediated by the risk perception. Thus, we ran a mediated model testing the relationship between scientific knowledge and cooperative behaviors (c) while adding to the model risk perception (b). See Figure 11 above.

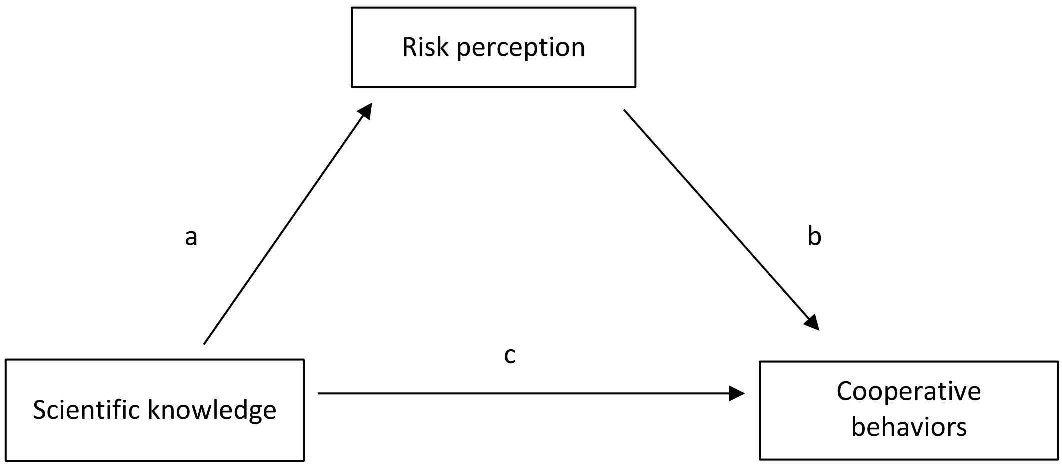



**Figure 11.** The mediation model of Hypothesis 5

We proceeded in this way separately for climate change and the SARS-CoV-2 pandemic, considering every single factor of risk perception in a separate mediation model. As for Hypotheses 2 and 3, we fully describe only the mixed models that revealed mediation effects among variables. For the climate change condition, in the first mediated model, first we considered the mediating role of the temporal scale. The results showed a main effect of the knowledge on cooperative behaviors: the higher was the level of knowledge the higher was the amount contributed in the games ($B = 3.17$; $SE = 1.09$; $z = 2.90$; $p = 0.004$), while the temporal scale and the scientific knowledge of the risk had no effect, respectively, on cooperative behaviors ($B = -0.03$; $SE = 0.06$; $z = -0.54$; $p = 0.59$) and temporal scale perception of the risk ($B = 1.56$; $SE = 0.87$; $z = 1.80$; $p = 0.07$). In addition, there was no mediation effect considering the temporal scale (*B* = -0.05; *SE* = 0.10; *z* = -0.52; *p* = 0.60).

The second mediation model of climate change considered the spatial scale as mediator. Results revealed a main effect of the scientific knowledge both on the spatial scale (*B* = 1.50; *SE* = 0.70; *z* = 2.14; *p* = 0.03) and on cooperative behavior (*B* = 2.98; *SE* = 1.09; *z* = 2.73; *p* = 0.006). The higher the scientific knowledge of the risk (i.e. climate change), the more it was considered as global. On the contrary, spatial dimension of risk perception did not predict the variance of cooperative behaviors (*B* = 0.09; *SE* = 0.07; *z* = 1.22; *p* = 0.22) and even in this model there was no mediation effect (*B* = 0.13; *SE* = 0.13; *z* = 1.06; *p* = 0.29). Results that were statistically significant for all the factors of the mediation model were the ones considering the likelihood of being impacted by a risk (see Table 10 and Figure 12 above). Knowledge had an effect both on the likelihood of being impacted by risk (*B* = 2.69; *p* = 0.005) and the social dilemma (PGG or IGG; *B* = 2.69; *p* = 0.01) in predicting cooperative behaviors, but its effect was greater for the IGG (*B* = 2.69). Moreover, the mediator of our model was significant too (*B* = 0.42; *p* = 0.004), hence the interaction between likelihood of risk perception and knowledge had an effect on cooperative behavior (*B* = 0.21; *p* = 0.003).

| | *B* | *SE* | *Z* | *P* |
|---|---|---|---|---|
| VD: Game (PGG vs. IGG) | | | | |
| Knowledge (c1) | 2.69 | 1.09 | 2.48 | 0.01 |
| Likelihood of risk (RP; b1) | 0.21 | 0.07 | 2.96 | 0.003 |
| M: Likelihood of risk (RP) | | | | |
| Knowledge (a1) | 2.02 | 0.72 | 2.80 | 0.005 |
| Indirect path | 0.42 | 0.21 | 2.03 | 0.04 |
| Total effect | 3.12 | 1.09 | 2.86 | 0.004 |

**Table 10.** Regressions and fixed effects of the mediated model of Hypothesis 5 for climate change considering risk perception (likelihood of risk), scientific knowledge (knowledge), and their interaction on cooperative behaviors (indirect path).

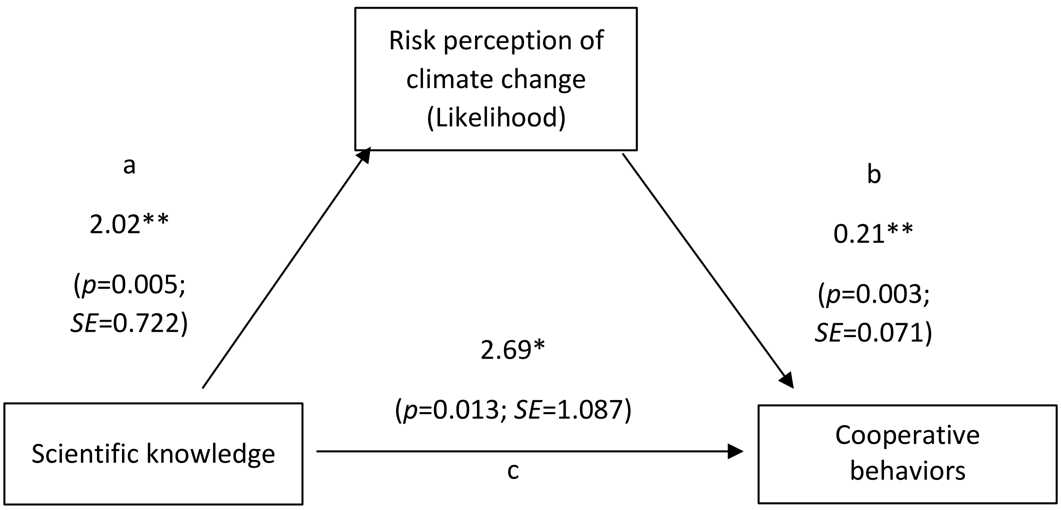



**Figure 12.** Mediated model of Hypothesis 5 with the variable of likelihood of being impacted by a risk (Risk perception), scientific knowledge and cooperative behaviors showing the associated values revealed from the analysis.

In the fourth mediation model for climate change, we considered the risk's characteristics, and results revealed significant effects for all the factors considered (see Table 11 and

Figure 13). In particular, the higher was the level of scientific knowledge the higher were cooperative behaviors (*B*= 2.66; *p*= 0.02) and the perception of climate change relying on its characteristics (*B*= 0.25; *p*= 0.01).

| | *B* | *SE* | *Z* | *P* |
|---|---|---|---|---|
| VD: Game (PGG vs. IGG) | | | | |
| Knowledge (c1) | 2.66 | 1.10 | 2.43 | 0.02 |
| Characteristics of risk (RP; b1) | 0.25 | 0.10 | 2.49 | 0.01 |
| M: Characteristics of risk (RP) | | | | |
| Knowledge (a1) | 1.79 | 0.51 | 3.54 | 0.000 |
| Indirect path | 0.45 | 0.22 | 2.04 | 0.04 |
| Total effect | 3.12 | 1.09 | 2.86 | 0.004 |

**Table 11.** Regressions and fixed effects of the mediated model for climate change considering risk perception (characteristics of risk), scientific knowledge (knowledge), and their interaction on cooperative behaviors (indirect path).

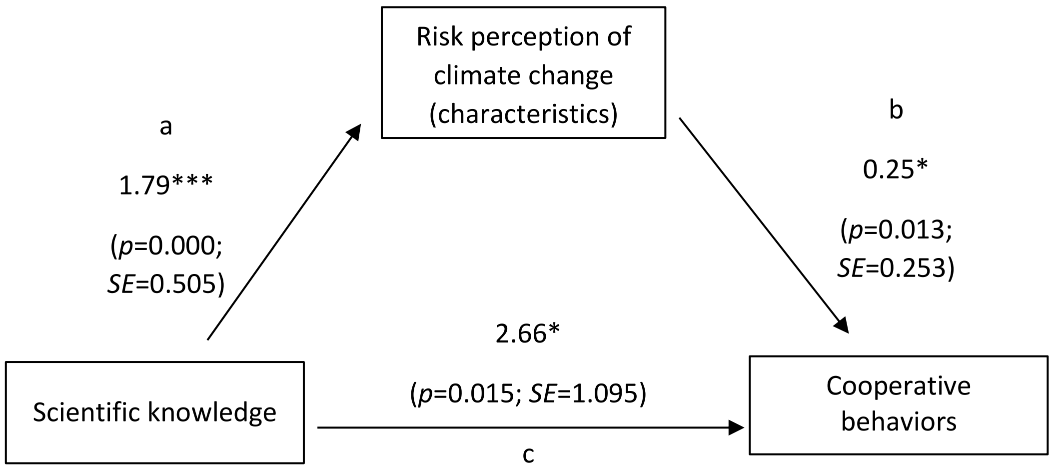



**Figure 13.** Mediated model of Hypothesis 5 with the variable of characteristics of a risk (Risk perception), scientific knowledge and cooperative behaviors showing the associated values revealed from the analysis.

In the last mediation model for climate change, we considered the risk's costs and we found that there was a significant direct effect of scientific knowledge on cooperative behaviors ($B$ = 3.14; $SE$ = 1.10; $z$ = 2.86; $p$ = 0.004) as well as on costs ($B$ = 1.99; $SE$ = 0.77; $z$ = 2.58; $p$ = 0.01), but the effect of costs on cooperative behaviors ($B$= -0.01; $SE$ = 0.07; $z$ = -0.18; $p$= 0.86) as the indirect effect were not significant ($B$= -0.02; $SE$ = 0.13; $z$ = -0.18; $p$= 0.86).

For the SARS-CoV-2 pandemic, we proceeded in the same fashion. In the first mediated model, neither scientific knowledge ($B$ = 0.77; $SE$ = 0.10; $z$ = 0.77; $p$ = 0.44 interaction of knowledge on temporal scale; $B$ = -1.61; $SE$ = 1.37; $z$ = -1.18; $p$ = 0.24 interaction of knowledge on games) nor the temporal dimension ($B$ = -0.06; $SE$ = 0.07; $t$ = -0.84; $p$ = 0.40) had statistically significant effects on cooperative behaviors. Therefore, the indirect effect was not significant too ($B$ = -0.04; $SE$ = 0.07; $z$ = -0.57; $p$ = 0.57). Instead, in the mediated model with spatial scale, we found that risk perception had an effect on cooperative behaviors ($B$ = 0.30; $SE$ = 0.08; $z$ = 3.57; $p$ = 0.000), while knowledge did not ($B$ = -2.14; $SE$ = 1.35; $z$ = -1.58; $p$ = 0.11). Knowledge did not have an effect on the spatial scale too (*B* = 1.60; *SE* = 0.80; *z* = 2.01; *p* = 0.05). Finally, mediation effect was not significant (*B* = 0.48; *SE* = 0.27; *z* = 1.75; *p* = 0.08). For the likelihood of being impacted by a risk (SARS-CoV-2 pandemic) there were no significant statistical effects (*B* = -1.54; *SE* = 1.37; *z* = -1.12; *p* = 0.26 effect of knowledge on games; *B* = -0.94; *SE* = 0.74; *z* = -1.27; *p* = 0.20 effect of knowledge on likelihood of risk; *B* = 0.13; *SE* = 0.09; *z* = 1.47; *p* = 0.14 effect of likelihood of risk on games; *B* = -0.13; *SE* = 0.13; *z* = -0.96; *p* = 0.34 indirect path). Then, we analyzed the risk characteristics, finding that cooperative behaviors were predicted by risk characteristics (*B* = 0.25; *p* = 0.005) and by the interaction effect (*B* = 0.53; *p* = 0.05; see Table 12 and Figure 14). Moreover, knowledge had an effect on the risk perception relying on its characteristics (*B* = 2.12; *p* = 0.005).

| | *B* | *SE* | *Z* | *P* |
|---|---|---|---|---|
| VD: Game (PGG vs. IGG) | | | | |
| Knowledge(c1) | -2.19 | 1.37 | -1.60 | 0.11 |
| Characteristics of risk (RP; b1) | 0.25 | 0.09 | 2.80 | 0.005 |
| M: Characteristics of risk (RP) | | | | |
| Knowledge (a1) | 2.12 | 0.75 | 2.83 | 0.005 |
| Indirect path | 0.53 | 0.27 | 1.99 | 0.05 |
| Total effect | -1.66 | 1.37 | -1.22 | 0.23 |

**Table 12.** Regressions and fixed effects of the mediated model for SARS-CoV-2 pandemic considering risk perception (risk characteristics), scientific knowledge (knowledge) and their interaction on cooperative behaviors (indirect path).

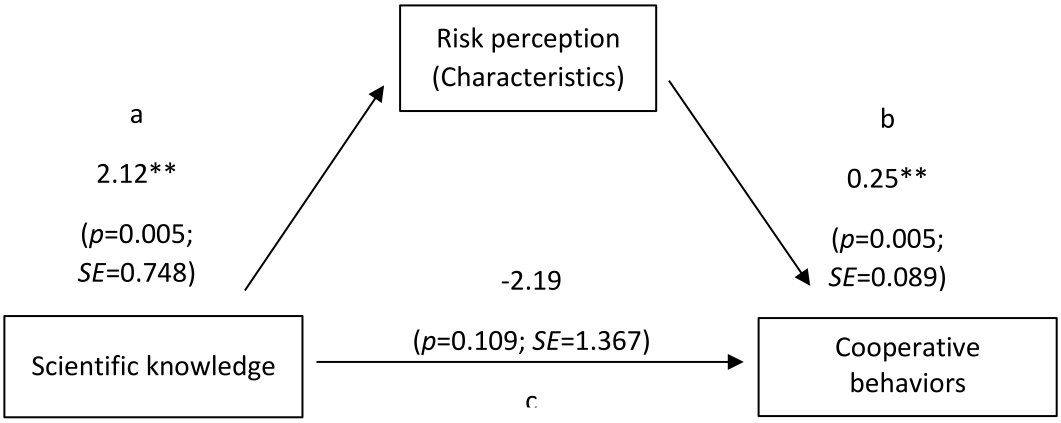



**Figure 14.** Mediated model of Hypothesis 5 with the variable of characteristics of risk (Risk perception), scientific knowledge and cooperative behaviors showing the associated values revealed from the analysis.

The final mediated model that we ran had the risk costs as the mediator. The results showed a statistically significant effect only for the scientific knowledge on the risk's costs ($B$=1.77; $SE$= 0.84; $z$= 2.10; $p$= 0.04).

## 6. Discussions

Comparing the SARS-CoV-2 pandemic and climate change, we structured our study and the hypotheses to analyze if and what kind of relationship there is between the exponential growth and risk perception (SARS-CoV-2 pandemic vs. climate change) and the effect of this relation on cooperative behaviors.

**The risk perception changes depending on the risk considered.**

We looked at the changes of the means of the two risks considered in our study (SARS-CoV-2 pandemic vs. climate change) in relation to the different factors of the risk perception (i.e., temporal scale, spatial scale, the likelihood of being impacted by the risk, risk's characteristics, and risk's costs). Therefore, we assessed that the risk perception of the SARS-CoV-2 pandemic should be higher than the risk perception of climate change. From the results emerged that for the majority of the risk perception factors we considered we cannot support our hypothesis. In particular, the temporal scale of action of the SARS-CoV-2 pandemic was perceived as closer than the one of climate change. Thus, the SARS-CoV-2 pandemic is perceived as a short-term risk whose effects are visible shortly. This result aligns with our hypothesis and previous literature because it has been demonstrated that present risks are perceived as more relevant and dangerous for people leading to a higher affective response triggering the "risk-as-feeling" system (Loewestein et al., 2001; Slovic et al., 2004). Specifically, climate change is perceived as an abstract issue to face in the future due to its features (Weber, 2010). On the other hand, the SARS-CoV-2 pandemic effects are visible daily, since we are still facing this pandemic. From the results emerged that both the risks are perceived as global issues and this is not in line with our hypothesis, besides it is in line with the literature which states that people agreed with the global spreading of climate change (Leiserowitz, 2007, 2020) and the SARS-CoV-2 pandemic () but the perception of them is linked to cultural factors (Kahan, 2012;

Dryhurst et al., 2021; van der Linden 2015; 2017) and to the relative geographic country position (Kim & Wolinsky-Nahmias, 2014). This last aspect that emerged from the scientific literature reflects our results of the t-test considering the likelihood of being impacted by one of the two risks. In our study, emerged that the likelihood was higher for climate change, in contrast with our hypothesis and with the temporal scale's results where the SARS-CoV-2 pandemic was perceived as the closest risk. We can explain these results relying on the role of previous experiences with climate change that left a negative affect on people who faced them (van der Linden, 2014) and when people face an extreme climate event the "availability heuristic" is triggered and the likelihood of the events is perceived higher than reality (Tversky & Kahneman, 1973). Moreover, we analyzed the risk characteristics finding that the risk perception was higher for climate change. This result is in contrast with our hypothesis because we supposed that the SARS-CoV-2 characteristics would have triggered the risk perception more. In particular, the SARS-CoV-2 characteristics are in the upper-right quadrant of the cognitive map of risk (Slovic, 1987), like climate change, but we can hypothesize a possible explanation for our result is that for the former it has already been found an effective solution and the spreading of the virus is decreasing, while for the latter the solution found till now are not enough effective, hence keeping a higher perception of risk (Ipsos, 2020; Verplanken et al., 2020). Finally, we measured the costs of coping with the risk (SARS-CoV-2 pandemic vs. climate change) and found that such costs are perceived as higher for the SARS-CoV-2 pandemic compared to climate change. This is in line with our hypothesis and with the literature referred to climate change because people's hesitancy to act for climate change is linked to the willingness to see and enjoy the benefits of their sacrifices, thus they are more willingness to renounce some benefits in the present for present (vs. future) issues, such as the SARS-CoV-2 pandemic (Chapman, 1996; Frederick et al., 2002; Milinsky, 2008; Weber, 2010).

**The type of risk modulates the level of cooperative behaviors.**

We hypothesized that depending on the risk condition (the SARS-CoV-2 pandemic vs. climate change), participants would have shown different cooperative behaviors (PGG vs. IGG). In particular, the level of cooperation would have been higher in the SARS-CoV-2 pandemic context than in the climate change one. From the results of the mixed models that we ran, we found that in the PGG there was no difference between the two risks conditions. This result is not in line with our hypothesis and we can explain it relying on the results of the previous hypothesis. In fact, both the considered risks are perceived as global issues and the difference in the costs for coping with them was little from a statistical point of view. Therefore, in the PGG, which considers the level of individual cooperation for a social issue, we could interpret the no difference between the two as the perception of them as two present issues (Verplanken et al., 2020). These could be explained by looking at the mass media information spread since, at the time of the data collection (September-October 2021), summer had just passed and in Italy, there have been many wildfires. Moreover, in literature is already known the role of the media information in shaping risk perception for both the SARS-CoV-2 pandemic (He et al., 2021; Savadori & Lauriola, 2021) and climate change (Weber, 2010). On the other hand, the t-test considering the IGG revealed that the cooperative behaviors for this game were higher in the climate change condition than in the SARS-CoV-2 pandemic one, and this result is in contrast with our hypothesis as well. But some recent literature reports that people expressed major concern for climate change comparing it with the SARS-CoV-2 pandemic (Ipsos, 2020; Verplanken et al., 2020).

Finally, it is interesting to observe that in general, our sample cooperated less in the IGG than in the PGG. This is in line with the literature and in particular with the “present bias” thus people generally give stronger weight to payoffs that are closer to the present time when considering trade-offs between two future moments (Zhao & Luo, 2021).

**The relationship between risk perception and cooperative behaviors.**

For Hypothesis 2 we assessed that there was a direct positive relationship between risk perception and cooperative behaviors, thus the increment of the former leads to an increment of the latter. We ran several mixed models, one for each factor of risk perception, considering the two versions of the cooperative game (i.e., PGG vs IGG). In the first mixed model, the type of game was the only predictor of the number of cooperative behaviors. In particular, our sample cooperated more in the PGG than in the IGG. As for the previous hypothesis, this result could be explained by the "present bias" (Zhao and Luo, 2021). In addition, relying on recent literature, we could say that both the problems arise social concern thus people perceive them as present issues (Ipsos, 2020; Verplanken et al., 2020) reducing the time preference in decision making. Specifically, people have the tendency to delay actions to cope with issues perceived as future which, instead, required present costs (Chapman, 1996; Frederick et al., 2002). For the spatial scale, what emerged is that people perceived both the risks as worldwide, and this led to a higher level of cooperation. This is in line with our hypothesis. It has already been demonstrated that these two issues have common features, as being globally spread (Fuentes et al., 2021). In addition, for both the SARS-CoV-2 pandemic and climate change it has been demonstrated that they require a worldwide response (Botzen et al., 2021; Fuentes et al., 2021; Manzanedo & Manning, 2020; Pasini & Mazzocchi, 2020). In particular for climate change, it has been demonstrated that the role of values at both personal and group levels is central to motivate people and to guide pro-environmental actions (Bouman et al., 2021). While, for the SARS-CoV-2 pandemic, the efficacy beliefs declined as self-efficacy, personal and collective efficacy helps promoting the protective behaviors (Caserotti et al., 2022; Dryhurst et al., 2020). Considering the likelihood of being impacted by one of the two risks of our study, the results of the mixed model revealed a main effect of the type of game on the PGG. Therefore, people cooperated more for present issues whose benefits would be for themselves and their own generation. Even in this case, the result could be explained by the "present bias" (Zhao & Luo, 2021). Moreover, in this analysis, we found an interaction between the likelihood of being impacted by one of the risks considered (SARS-CoV-2 pandemic vs. climate change) and the type of game (PGG vs. IGG). Specifically, the higher was the likelihood perceived the higher was the amount donated in one of the games, and in particular, we found that this interaction is more pronounced considering the IGG. A possible explanation for the latter is that people are more willing to cooperate since they have faced in the near past previous experiences with both risks. Indeed, previous experiences elicited a higher risk perception (Dryhurst et al., 2020; Gerhold, 2020; He et al., 2021; van der Linden, 2014) and consequently a higher sense to act to reduce it (risk-as-feeling response; Loewenstein et al., 2001; Slovic et al., 2004). Moreover, in line with this, the more people have previous experiences with a risk the more the "availability heuristic" is triggered leading them to overestimate the likelihood of the activating event (Tversky & Kahneman, 1973). On the contrary, when we considered the characteristics of the two risks, we found a main effect of the type of game which revealed a lower level of cooperation in the IGG. The possible explanation is that in this mixed model we marked the characteristics of the risk (SARS-CoV-2 pandemic vs. climate change) that should have emphasized the risk perception associated with each risk leading to an activation of the risk-as-feeling response (Loewenstein et al., 2001; Slovic et al., 2004). In fact, it has been theorized in the "cognitive map of risks" (Slovic, 1987) that when the risk's characteristics are more salient the risk perception is higher. Specifically, the SARS-CoV-2 pandemic is perceived as a future risk (Weber, 2010) and, on the contrary, climate change as a present risk

(Savadori & Lauriola, 2021). Finally, we analyzed if the costs changed the level of cooperation but we did not find any effects. A possible explanation could rely on the socio-demographic characteristics of our sample, in particular the gender (F= 256) and the age (mean= 28.76). Indeed, for both issues, it has been demonstrated how these two social-demographic variables are able to change risk perception (Dryhurst et al., 2020; van der Linden 2015; 2017).

**Cooperative behaviors should depend on the level of time discounting, whose effects should be mediated by the perception of costs and benefits of cooperation.**

We ran two mediation models to test our hypothesis, one considering the PGG and one considering the IGG, and two regression models to test the direct relationship between temporal discounting and cooperative behaviors without considering other variables. In both cases, there were no mediation effects, but only the main effects of cost and benefits on cooperative behaviors (PGG vs. IGG) and not always the direct relation between temporal discounting and cooperative behaviors (PGG vs. IGG). For what concern the results emerged with the PGG, we can explain the absence of a mediation effect and the actual direct relationship between temporal discounting and cooperative behaviors, relying on the role of media and indirect experience through information in keeping people constantly aware of both problems (He et al., 2021; Savadori & Lauriola, 2021). Moreover, a communication frame that combines the consequences of both risks leads to a similar perception of them (Botzen et al., 2021) and, thus, the mediation role of costs and benefits and the temporal discounting are useless in relation to the cooperative behaviors. On the contrary, benefits and costs had a main effect on PGG. Therefore, this could be due to an economical evaluation of the amount of money shared. Indeed, increasing the amount of money shared in the PGG, the benefits perceived increased too, while, on the contrary, the costs decreased. The same results and the same considerations could be used to explain the results of the mediation model and the regression model with the IGG. Finally, it is important to highlight that looking at the *B* of both costs in PGG e IGG, the latter is more negative than the former. This means that people perceived the costs for the IGG higher than the costs for the PGG, which is in line with the literature on temporal discounting (Chapman, 1996; Frederick et al., 2002).

**How negative affect impacts risk perception relying on the exponential growth of risk.**

From the several correlations that we ran considering the two risks, separately, and the mental images (declined as the valence of the first mental image and the average valence of mental images) we found that for both the type of risks, the highest correlation was between the two measures of the affect, thus between the valence of the first mental image and the average valence of the mental images. Therefore, we can interpret this data as in line with the purpose of our study: that the affect is related and used to interpret the risks' exponential growth. This novelty could be added to reinforce the importance and the central role of affect in risk perception (Leiserowitz, 2006; Smith & Leiserowitz, 2012; van der Linden, 2014). On the contrary, the affect did not correlate with the different factors of risk perception in both the risks (SARS-CoV-2 pandemic vs. climate change), thus negative affect did not improve risk perception. A possible explanation for these results is that there are many other factors that we did not consider, such as socio-cultural and socio-demographic factors or the knowledge of the risks that shape the risks' perception or the difficulty of the interpretation of the graph.

**The level of scientific knowledge about the risk leads to a higher risk perception that mediates cooperative behaviors.**

We ran several mediation models, considering separately the SARS-CoV-2 pandemic and climate change, to identify whether risk perception had a mediation relationship between the scientific knowledge of the risk and the cooperative behaviors. Thus, we considered a different factor of the risk perception in each mediation model. In the SARS-CoV-2 pandemic, the temporal scale mediation model revealed that there were no effects and the same emerged considering the likelihood of being impacted by the SARS-CoV-2 pandemic. We suppose, that the absence of effects in the former is due to the ongoing situation of the pandemic and other norms and cultural factors that have not been considered in this mediation model but are known from the literature to be strictly related to the knowledge (Dryhurst et al., 2020; Zwart, 2009). Therefore, the absence of effects in the likelihood of being impacted by the SARS-CoV-2 pandemic could be explained by the fact that the virus was already widespread and that at the end of the summer positive cases were few. On the contrary, there was a main effect of the knowledge on the risk perception when considering the costs. This could be interpreted as a debiased interpretation of the costs of the SARS-CoV-2 pandemic due to the scientific knowledge that reduced the worldview beliefs (Kahan, 2012). Considering the spatial scale, emerged two principal effects: the effect of scientific knowledge on risk perception and the effect of risk perception on cooperative behaviors. Notwithstanding, the mediation effect of the spatial scale was not significant. We can explain the two main effects relying on the previous literature which states that, in general, scientific knowledge has a main role in shaping risk perception (Kahan, 2012), and, relying on our results, the risk perception is higher as the scientific knowledge is higher. While, the perception of the risk as more global leads to a higher number of cooperative behaviors, which is in line with the concept of self and collective efficacy to face the virus (Caserotti et al, 2022; Dryhurst et al., 2021). In the SARS-CoV-2 pandemic condition, there was a mediation effect of scientific knowledge and characteristics of risk on cooperative behaviors. We could explain it considering that scientific knowledge could activate the "analytic system" (Epstein, 1994) and therefore a risk-as-analysis response (Slovic et al., 1981). At the same time, the characteristics of risk are more salient, increasing their vividness on the "cognitive map of risks" (Slovi, 1987), leading to a coactivation of the "experiential system". This coactivation explains a higher number of cooperative behaviors due to the "risk-as-analysis" and "risk-as-feelings" responses associated with these two systems (van der Linde, 2014). For the climate change mediation models, the results are a little different. Indeed, considering the temporal scale there was a main effect of the knowledge on cooperative behaviors and this could be explained as above, hence with the role of scientific knowledge in activating the risk perception in both our cognitive processes (van der Linden, 2014). Then the scientific knowledge had a main effect both on risk perception and on cooperative behaviors, and can be explained as previously. These main effects emerged in the mediation model considering the spatial scale and in the mediation model considering the costs. When we had considered the likelihood and the characteristics of climate change what emerged is that in both the mediation models all the regressions were statistically significant. Therefore, we suggest that considering the more central factor of the risks (i.e the likelihood and the characteristics) the role of the scientific knowledge is even more relevant in shaping the climate change perception, maybe because this combination elicits more vivid representations of climate change's dangers.

### 6.1 Limits of our study

It is important to note that the present study has some limitations. First of all, the sample of participants was composed mainly of university students, hence our sample's mean age was low (M age= 28.76). Moreover, the female participants were almost double of the males or other not specificized participants. Both these two are limits to the generalizability of our results. Further, in particular, for the risk perception, it is known that gender has a relevant role in changing the perception of risk (i.e. females have a higher perception of risks; de Zwart et al., 2009; Dryhurst et al., 2020; Gerhold, 2020; Han et al., 2021; He et al., 2021; Rubaltelli et al., 2020; Schneider et al., 2021A; Zhong et al., 2021). Secondly, we used different rating scales (0 to 100, 1 to 5, 1 to 7) and in the majority of questions, we used the rating scale going from 0 to 100 increasing the variability of the results in our study. Thirdly, the length of our study (almost 20 minutes) could have inducted a loss of motivation in completing it. Finally, we collected data between the end of September and October 2021, i.e., when the media information about the SARS-CoV-2 pandemic was not so widespread and, on the contrary, Italy was facing the effects of huge wildfires (e.g. Sicily, Sardinia, Calabria, Apulia).

### 6.2 Future researches

The purpose of future researches is to implement the exploratory analysis in the models and the results that we found to reinforce our lack. In particular, we suggest investigating the role of gender, warm-glow, and cultural values in shaping the risk perception of these two risks compared. Then future research could focus more on the psychological consequences of the SARS-CoV-2 pandemic and of climate change (e.g., climate anxiety). Indeed, the psychological effects of climate change and the SARS-CoV-2 pandemic are already known, otherwise, as for climate change, it has been demonstrated a new form of anxiety, i.e. the climate change anxiety, maybe for the SARS-CoV-2 pandemic and its preventive measures new associated psychological diseases could emerge. Finally, it could be interesting to investigate more deeply the role of social media in changing the influence in perceiving the curve of these two exponential growths. Therefore, always considering the exponential growth and the associated exponential bias, it could be interesting to empathize the role of media communication on shaping risk perception analyzing how and if the curve associated with these risks change or not depending on the type of message received (focused on objective information or on psychological information).

### 6.3 Conclusions

The present study compared how two global issues are perceived relying on their characteristics. It highlighted the similarities and differences, with the scope to investigate the reasons and what relation there is behind the different perceptions and social responses to these two issues that are more similar to each other than it seems. From our analysis, we can conclude that the costs of the SARS-CoV-2 pandemic are the only factor that guides people in perceiving it as higher than climate change and to cooperate less for future generations. Moreover, our analysis revealed that the likelihood of being impacted by a risk leads to a major level of risk perception and to cooperate with other people for the benefit of future generations. For what concerns the costs and the benefits, it is necessary to specify that they do not have a mediation relationship between time discounting and cooperative behaviors, but they influence the cooperative behaviors. Specifically, a higher level of benefits led to a higher level of cooperation in both the game considered. Further, we confirmed the central role of affect in risk perception, even though we did not find that it is the cause of an increase of the risk perception itself. Finally, risk perception has a controversial role in the mediation relationship between scientific knowledge and cooperative behaviors because it was an effective mediator considering a few of the risk perception factors. This study is useful because it compares two global issues using the exponential bias as a cognitive feature to better comprehend which are the variable implied in the different perceptions of these two risks.

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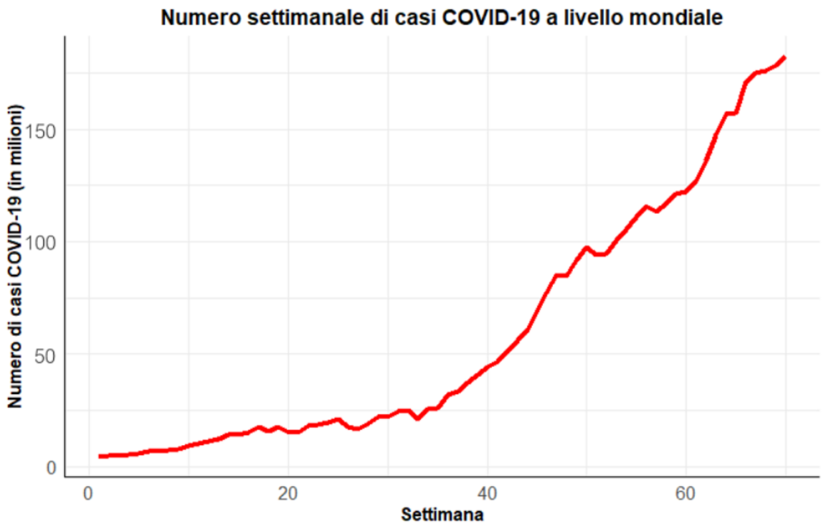
## APPENDIX

### Section A




The number of COVID-19 cases worldwide has been recorded since January 22, 2020. The graph above represents the number of weekly new cases of COVID-19 globally recorded up to May 19, 2021.

**Figure 1.** Control condition and scenario of the SARS-CoV-2 pandemic created using the curve of the tons of $CO_2$ emitted per million globally each year from 1881 to 2021.

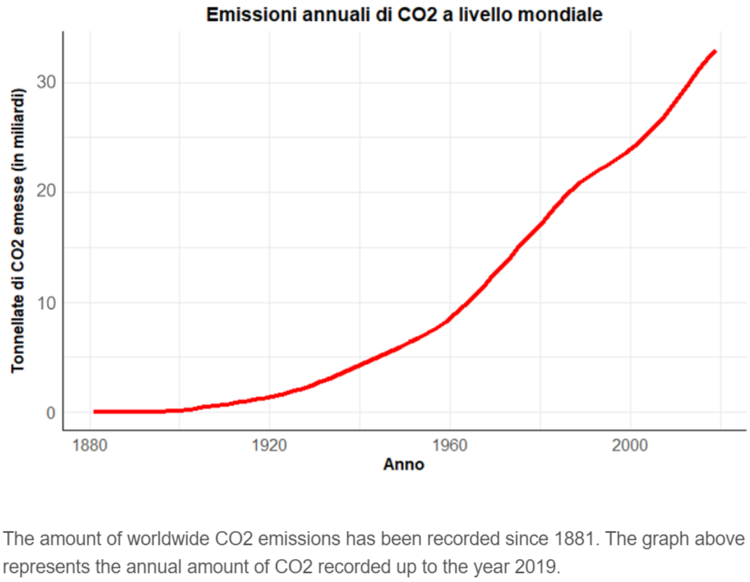



**Figure 2.** Control condition and scenario of climate change condition using the curve of weekly average of new cases daily of SARS-CoV-2 in millions registered globally from January 22, 2020, to May 19, 2020.

## Section B

Scenarios presented to participants during the CTB.

Decision number 1:

| | | | | | |
|---|---|---|---|---|---|
| Today: 19.00€ AND in 5 weeks: 0.00€ | Today: 15.20€ AND In 5 weeks: 4.00€ | Today: 11.40€ AND In 5 weeks: 8.00€ | Today: 7.60€ AND In 5 weeks: 12.00€ | Today: 3.80€ AND In 5 weeks: 16.00€ | Today: 0.00€ AND In 5 weeks: 20.00€ |

Decision number 2:

| | | | | | |
|---|---|---|---|---|---|
| Today: 18.00€ AND In 5 weeks: 0.00€ | Today: 14.40€ AND In 5 weeks: 4.00€ | Today: 10.80€ AND In 5 weeks: 8.00€ | Today: 7.20€ AND In 5 weeks: 12.00€ | Today: 3.60€ AND In 5 weeks: 16.00€ | Today: 0€ AND In 5 weeks: 20.00€ |

Decision number 3:

| | | | | | |
|---|---|---|---|---|---|
| Today: 17.00€ AND In 5 weeks: 0.00€ | Today: 13.60€ AND In 5 weeks: 4.00€ | Today: 10.20€ AND In 5 weeks: 8.00€ | Today: 6.80€ AND In 5 weeks: 12.00€ | Today: 3.40€ AND In 5 weeks: 16.00€ | Today: 0€ AND In 5 weeks: 20.00€ |

Decision number 4:

| | | | | | |
|---|---|---|---|---|---|
| Today: 16.00€ AND In 5 weeks: 0.00€ | Today: 12.80€ AND In 5 weeks: 4.00€ | Today: 9.60€ AND In 5 weeks: 8.00€ | Today: 6.40€ AND In 5 weeks: 12.00€ | Today: 3.20€ AND In 5 weeks: 16.00€ | Today: 0€ AND In 5 weeks: 20.00€ |

Decision number 5:

| | | | | | |
|---|---|---|---|---|---|
| Today: 14.00€ AND In 5 weeks: 0.00€ | Today: 11.20€ AND In 5 weeks: 4.00€ | Today: 8.40€ AND In 5 weeks: 8.00€ | Today: 5.60€ AND In 5 weeks: 12.00€ | Today: 2.80€ AND In 5 weeks: 16.00€ | Today: 0€ AND In 5 weeks: 20.00€ |

Decision number 6:

| | | | | | |
|---|---|---|---|---|---|
| Today: 11.00€ AND In 5 weeks: 0.00€ | Today: 8.80€ AND In 5 weeks: 4.00€ | Today: 6.60€ AND In 5 weeks: 8.00€ | Today: 4.40€ AND In 5 weeks: 12.00€ | Today: 2.20€ AND In 5 weeks: 16.00€ | Today: 0€ AND In 5 weeks: 20.00€ |