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Risk Perception and Risk Talk:

The Case of the Fukushima Daiichi Nuclear Radiation Risk

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Abstract

Individuals' perceptions and their interpersonal communication about a risk event, or risk talk, can play a significant role in the formation of societal responses to the risk event. As they formulate their risk opinions and speak to others, risk information can circulate through their social networks and contribute to the construction of their risk information environment. In the present study, Japanese citizens' risk perception and risk talk were examined in the context of the Fukushima Daiichi nuclear radiation risk. We hypothesized and found that the risk information environment and risk literacy (i.e., competencies to understand and use risk information) interact to influence their risk perception and risk talk. In particular, risk literacy tends to stabilize people's risk perceptions and their risk communications. Nevertheless, there were some subtle differences between risk perception and communication, suggesting the importance of further examination of interpersonal risk communication and its role in the societal responses to risk events. (154 words)

Keyword: risk perception, risk communication, interpersonal communication, risk literacy

1. INTRODUCTION

Mass communication and public perception are well recognized as major determinants of societal responses to a risk;[1,2] however, less well understood is the role played by interpersonal communication, or *risk talk*, in the social and cultural processes surrounding the risk. Although mass media and other institutional mechanisms often initiate the process of social diffusion of risk information, the general public is not its passive recipients, but active participants in the construction of societal responses to the risk. As they engage in social interactions and talk about the risk (social amplification of risk[1,2]: for its empirical use, see e.g., Binder, Scheufele, Brossard, & Gunther[3], 2011; Burns et al.[4]; Mase, Cho, & Prokopy[5] ; Renn, Burns, Kasperson, Kasperson, & Slovic [6]), interpersonal communication can amplify or attenuate the public perception of risk.[7,8]

Particularly important in this process is the role of the general public as disseminators of risk information. As the two-step flow model of communication recognized a long time ago,[9,10] individuals actively engage in the dissemination of mass communicated information through their social networks. A variety of information diffuses through social networks and gets amplified or attenuated in interpersonal discussions,[11] including information about controversial social issues such as climate change,[7] health information,[12] environmental issues,[13] and social stereotypes.[14] Citizens thus not only receive risk information from their information environment, but also actively construct the information environment for each other, and they sample information from it to formulate their judgments.[15,16]

Although information senders may tend to amplify risk in interpersonal communication,[17] little is known about how different people communicate diverse risk information. We suggest that interpersonal communications about mass communicated information is likely to be shaped by the communicators' risk literacy – individual differences in how well equipped they are to understand the structure and content of communicated risk information.[18] Risk literate people are likely to actively interpret communicated risk information and communicate it to others in their social networks. When a risk is well known in the society (i.e., unless it is a new risk), risk literate citizens are likely to have formed their risk opinions and to confidently communicate information in line with their views.

Using data of 1800 respondents about the radioactive food contamination risk in the wake of the Fukushima Daiichi Nuclear Disaster in Japan, this paper examines the effects of two broad classes of determinants of risk perception and risk talk: the information environment and individual characteristics of the citizens. On the one hand, the information environment as people perceive it and receive risk information from it is without a doubt a significant influence on how they perceive a societal risk and talk about it. On the other hand, they process risk information while bringing their individual characteristics to bear on the obtained information. Aside from the demographic characteristics such as gender, age, education, and location of residence relative to the Nuclear Disaster, as we detail later, two classes of individual characteristics play a significant role: people's risk literacy – their ability to think critically and make judgments based on the information drawn from the information environment – and critical thinking attitude – general attitudes towards critically evaluating information and reflectively drawing a conclusion.

In examining the effects of the information environment and individual characteristics, we also explore how different risk talk is from risk perception. To be sure, risk perception may be an individual's judgment of risk, and therefore it is likely to be highly correlated with risk talk. However, when risk information is talked about, a variety of interpersonal contextual factors are likely to influence and shape its formulation and content. Furthermore, potential consequences of risk talk on societal responses to risks are quite different. Those who express their risk opinions forcefully are likely to influence others' opinions and may cumulatively influence the subsequent social dynamics surrounding societal responses to a risk. It is useful to explore how people with different risk literacy respond to risk relevant information in their private perception and interpersonal expressions. Figure 1 schematically represents a conceptual framework we used in examining risk perception and risk talk in the case of Fukushima Daiichi nuclear radiation risk.

1.1. Information Environment about Risk

In the contemporary risk society,[19,20] the information environment contains diverse perspectives on a given risk. The diversity of risk perceptions in contemporary society is exemplified by cultural theory of risk[21,22] among others, according to which people who are located in a different social structure and who endorse different ideological orientations perceive risks differently.[23,24] For instance, those who endorse more egalitarian orientations tend to regard environmental issues as more risky than those who endorse more conservative orientations; however, conservatives tend to regard issues about law and order as riskier than egalitarians.[24] Consequently, the contemporary information environment is likely to contain a diverse mixture of information and opinions, some of which emphasize, while others deemphasize, risk.

1.1.1. Perceived Risk Opinion Distribution (PROD)

Reflecting this cultural diversity, it is likely that people have some ideas about the distribution of risk opinions in the society. Given a scale of perceived risk (e.g., a five point scale such as 1 = not at all risky to 5 = extremely risky), people can estimate how many out of 100 would respond by selecting 1, 2, etc.[25] to draw out a distribution of risk opinions. Indeed, social psychological research has found that people have a fairly accurate perception about the distribution of attitudes although there are some systematic biases.[26] This notion is analogous to what communication researchers call perceived opinion climate,[27-30] that is, people's perceptions of the distribution of others' opinions in quasi-statistical sense [31]. As Noelle-Neumann [32,33] noted, people may express their opinions differently depending on their perceptions of others' opinions. They tend to avoid expressing what they perceive to be minority opinions, thus reducing the chance of their opinions being heard by others. This may result in a further shrinkage of the opinion minority. Noelle-Neumann called this dynamics a spiral of silence.

Similarly, we suggest that a perceived distribution of risk opinions can affect people's risk perception, and particularly, risk talk. People are likely to talk about a risk in a way that is in line with what they perceive is "normative" in their social environment. Past research suggests that two characteristics of the perceived distribution – mean and standard deviation – are likely to have significant effects on their own risk perception and risk talk. First of all, it is well known that people's perceived descriptive norm – the *mean* of the perceived distribution of behaviours – is highly predictive of their own behaviours (e.g., Cialdini *et al.* (34) , see Manning(35), for meta-analytic review). It is likely that the mean of the *p*erceived *r*isk *o*pinion *d*istribution (PROD) is predictive of risk perception and likewise risk talk. In line with this reasoning, Tsfati et al. (29) found that people's perceived opinion climate was a significant influence on their own opinion. Similarly, Shen and Wang (27) found an effect of people's perceived opinion climate on their intention to express their true opinions.

Furthermore, the variability around the mean – the *standard deviation* of the PROD – may also impact risk perception and risk talk. There are two potential roles that variability in the PROD may play. First, a perceived dispersion of a PROD can reflect the perceived tightness of a descriptive norm. If risk opinions are seen to be tightly distributed around the mean, i.e., the descriptive norm, people perceive a greater consensus around the norm, and a norm seen to be consensually held may exert a stronger effect than when people see there are diverse risk opinions. This line of reasoning suggests that the standard deviation of a PROD can moderate the effect of the mean of the perceived opinion distribution on risk perception.

Second, the perceived dispersion of the risk opinions may have a main effect on perceived risk perception and communication. Smithson's[36] research suggests that people may perceive a greater risk when they think that the risk opinions are highly variable than when they are not. He argued that there are two forms of ambiguity in risk information communication. One is *source ambiguity* in which information sources agree that there is mixed evidence for risk. In other words, although risk information is variable, everyone agrees that it is variable. The other is *source conflict* in which information sources disagree such that one source says there is evidence of risk, but the other says there is no evidence of risk. He found many instances of *conflict aversion.* That is, people were more averse to source conflict than to source ambiguity. For instance, one of his experiments presented two scenarios that describe a controversy over whether aluminium causes Alzheimer's disease or not. In the conflictual scenario, half the experts said there was a link, whereas the other half said there was no link; in the ambiguous scenario, all experts said that half the studies showed a link, whereas the other half did not. When asked which scenario would make them feel more concerned about the risk, a majority said the conflict scenario would make them more concerned. We surmised that when risk opinions are perceived to be conflicting, a PROD may be seen to be highly diverse (i.e., greater standard deviation in PROD). This suggests that a more variable PROD may result in a greater risk perception.

In the current study, we aim to measure people's perceived risk opinion distribution (PROD) to index the perceived risk norm and the perceived dispersion and to investigate their effects on risk perception and risk talk, and hypothesize that:

H1: the higher is the mean of the PROD, the higher is risk perception and risk talk.

H2: the greater is the standard deviation of the PROD, the higher is risk perception and risk talk.

H3: the standard deviation of the PROD moderates the effect of the mean of the PROD on risk perception and risk talk, so that the mean of the PROD correlates with risk perception and risk talk more when the standard deviation of the PROD is smaller.

1.1.2. Media Presentation of Risk Information.

In addition, we experimentally present source conflict (vs. source ambiguity) and examine its effects on subsequent risk perception and risk communication. We surmise that perceived risk opinion distribution captures individuals' perceptions of their risk information environment, that is, what sorts of risk opinions are held in their social environment. In contrast, a media presentation of risk information provides risk information to the individuals in their *immediate* information environment *in situ*. In the conflict condition, one information source presents two arguments that emphasize risk, but the other information source presents two arguments that deemphasize risk; in the ambiguous condition, one information source presents one risk-emphasizing and one risk-deemphasizing argument, and the other information source too presents one risk-emphasizing and one risk-deemphasizing argument.

H4: risk perception and risk talk are likely to be greater in the source conflict than in the source ambiguity condition.

1.2. Critical Thinking: Risk Literacy and Critical Thinking Attitudes

People process risk information sourced from the information environment against their background and individual characteristics. Aside from demographics such as age, gender, and education, we suggest that people's tendency to engage in critical thinking is central to their risk information processing. Critical thinking is a deliberative and reflective processing of information with a view to reaching a logical and unbiased conclusion on the basis of evidence, so as to make well informed decisions about beliefs and actions[(37)] (see also Kusumi et al.[(38)]). People's motivation to engage in critical thinking is captured by *critical thinking attitudes* (CTA) [(39)]– general attitudes towards processing information in a reflective manner. Those who have positive attitudes towards reflective processing of information are more likely to engage in critical thinking. In the context of risk information processing, critical thinking attitudes scaffold a set of competencies relevant for the processing of that particular risk information. We call these competencies *risk literacy* [40]. Risk literacy consists of the ability (a) to acquire and comprehend risk relevant information, (b) to understand policies and strategies to reduce risk, and (c) to carry out relevant risk reduction behaviours[41] (Fig. 2).

In the context of the Fukushima Daiichi Nuclear Disaster, we suggest that risk literacy includes both scientific literacy and media literacy. Scientific literacy is defined as knowledge of the basic science and scientific method, and ability to think critically about information based on scientific data.[41] Scientific literacy was critical in the present case because people needed to process complex and often highly technical information about the nature of scientific research and technological safety about nuclear power generation, nuclear radiation, and scientific evidence for and against radiation risks. To support this risk information processing, *General Scientific Literacy* (GSL) is necessary, namely, general knowledge about basic science and scientific methodology acquired from science class during school and through other sources.[42] GSL, however, needs to be supplemented by *Specific Scientific Literacy* (SSL), i.e., knowledge about a specific domain relevant for a risk issue, which, in the present case, involves knowledge about nuclear radiation.

Nevertheless, scientific literacy is insufficient for appropriate processing of risk information. In many contemporary risk events including the case of the Fukushima Daiichi, risk information is often sourced from mass media. To process media information appropriately, *Media Literacy* (ML) is necessary to augment scientific literacy. If scientific literacy provides people with the competence to process the content of the scientific risk information, media literacy is about the source of the risk communication – the competencies to critically interpret the risk information presented by a communication medium and to actively engage with the issue on hand[43]. This includes the understanding about media coverage and presentation of risk information (e.g., selectivity of media coverage, editorial processes in media presentation), and motives that may drive the media coverage and presentation (e.g., profit motive). In total, media literacy is an ability to access, analyze, and evaluate mass media, and apply critical thinking skills to understand messages from mass media and the internet (e.g., Buckingham[43]).

Thus, risk literacy enables people to process risk information competently, and critical thinking attitudes motivate them to engage in critical thinking about the risk information. In combination, risk literacy and critical thinking attitudes can play a significant role in people's critical thinking about information processing and subsequent interpersonal communications about a risk.

What role do these characteristics play in the context of the Fukushima Daiichi Disaster? Do risk literate and critically thinking individuals respond sensitively to any media information or are they more likely to be unmoved? We suggest that risk literacy and critical thinking attitudes are likely to have a stabilizing effect on risk perception and to act as a facilitator of risk opinion communication. This is because, as we will discuss in greater detail later, the issue about nuclear radiation was already generally known in society in the Fukushima case. In this context, risk literate and critically thinking citizens are likely to have already acquired information relevant for the issue, understood it, and thought about how to deal with the risk. In other words, risk literate and critically thinking individuals would have formed their informed opinions about the risk prior to receiving further information in our experiment, and are less likely to be influenced by this additional information. In contrast, those who are less risk literate or critically thinking are more likely to be influenced by information in the experiment – this is because the information presented in the experiment is more likely to be novel or less likely to have formed their own personal opinions, and therefore it is likely more impactful to those who are less risk literate. This line of reasoning suggests that more risk literate and critically thinking individuals are less likely to revise their risk perception about a well-known risk issue in light of the risk relevant information presented in the study.

H5: Critical thinking, general scientific literacy, specific knowledge about the risk issue, and media literacy tend to stabilize risk perception, so that risk perception prior to exposure to information would predict risk perception more strongly if people have stronger critical thinking attitude (CT: H5.1), more general scientific literacy (GSL: H5.2), greater knowledge about the specific risk issue (SSL: H5.3), and greater media literacy (ML: H5.4).

1.3. Context of the Present Study

To facilitate the understanding of the current study, it is useful to provide additional background information about the context of the current study. Subsequent to the Great East Japan Earthquake of March 11, 2011, radioactive substances were released due to the meltdown of the Fukushima Daiichi Nuclear Power Plant. This equalled in magnitude to the Chernobyl disaster of 1986, classified at the maximum level of severity on the International Nuclear Event Scale, causing a great deal of public concern about the risk of nuclear radiation of agricultural products. The national government prohibits the sale of food products with a nuclear radiation level above its safety standard and the radioactive material has reduced with a passage of time since the Fukushima disaster[44-46]; however, even two to three years after the disaster, approximately 50% of the people surveyed in 2013 and 2014 still expressed a concern about radiation risks of food products.[47]

The high level of public concern can be understood against the history of nuclear power in Japan. Starting in 1963, nuclear power provided 28.6% of electricity prior to the 2011 disaster.[48] Nevertheless, together with Japan's experiences with nuclear warfare,[49] the public concern about nuclear radiation risks strengthened following the 1999 Tokaimura JCO nuclear radiation leak.[50] Presumably due in part to the successive Japanese governments' campaigns for nuclear power,[51] the percentage of the public who expressed concern about nuclear power remained relatively low at 20-30%, but it jumped to 70% following the 2011 Fukushima incident. [52]

The information environment immediately following the Fukushima Daiichi meltdown was characterized by a high level of uncertainty and ambiguity. Kinoshita [51] observed that the government's risk communication tended to present one-sided information emphasizing safety while weak in coherence and scientific evidence. In addition, a number of expert opinions emphasizing the risk of nuclear radiation were released through a variety of media including mass communication and other internet blog sites, further diversifying the information available to the general public.[47] In other words, the Japanese public was confronted by the information environment that was ambiguous (one information source citing both risk and safety of radioactive contamination) at times and conflicting (one side emphasizing risk, while the other side emphasizing safety) at other times, with the media coverage fuelled by somewhat contradictory motivations of objectivity and sensationalism.[53]

Against this broad background, our experiment presented conflicting or ambiguous media information that is similar to and reflective of the existing information environment in Japan. Our primary focus was on how citizens with different levels of risk literacy and critical thinking attitudes respond to this potentially confusing information environment in terms of their risk perception and interpersonal communication.

2. Method

2.1. Participants

One thousand and eight hundred (922 males and 878 females, *M*=43.4 years old) respondents participated in the online survey conducted in March, 2014. The respondents resided in the area damaged by the Great East Japan Earthquake (Fukushima, *n*=171, Miyagi, *n*=415), and the Tokyo Metropolitan area (Tokyo, *n*=645; Chiba, *n*=286, and Saitama, *n*=283). Respondents were required to have an education level higher than two years post-secondary education because the presented information was complex and this level of education may be required to ensure the respondents' adequate comprehension of the material. In addition, respondents were required to be married with at least one child below high school age. This was because this demographic group would regard the nuclear radiation risk as more relevant to them and their family.

2.2. Materials and Procedure

2.2.1. Risk Perception of Radiation

A question was asked to measure risk perception of low-dose radiation from food: "How much of a risk do you think an exposure to low-dose radiation from food is to human health?" (1=Not dangerous; 2=More not dangerous than dangerous; 3=Scientifically uncertain and hard to tell, or I don't know; 4=More dangerous than not dangerous; 5=Dangerous).

2.2.2. Risk Literacy Scales

Specific scientific literacy was measured by five knowledge questions about radioactivity constructed from the government information.[54] They asked whether the respondents knew about radiation, the distinction between Becquerel (Bq) and Sievert (Sv), and so on. The response scale had three points: 2="I had known about it before reading," 1="I understood the meaning after reading the information," and 0="I couldn't understand the meaning even after reading the information" (5 items, Zumbo's ordinal α =.90).

General scientific literacy was measured by General scientific literacy scale (seven questions) about scientific methodology (e.g., importance of replicability), scientific data (e.g., importance of sample size), and science reporting (e.g., differences between journal article and conference presentation). [55] The concept and format of this scale was similar to NSKS (nature of scientific knowledge scale).[56] However, except for one item, which was a direct translation of the NSKS, the items were developed for this study to suit the Japanese cultural context.. There were three options (True, False, Don't know) for each question, and the number of correct answers indexed general scientific literacy (7 items, Zumbo's ordinal α=.71).

Media literacy was measured by Media literacy scale for nuclear risk from Kusumi[47] and Kusumi and Mastuda[57] . They asked about knowledge concerning mass media (e.g., media and newspapers are for profit companies), and their handling of mass communicated information (e.g., evaluating media information by checking it with other media sources or internet sites). The response scale had five points (1:Disagree – 5:Agree) (5 items, Cronbach α =.77).

2.2.3. Critical Thinking Attitude

A short version of Hirayama and Kusumi's[58] Critical Thinking Scale for Japanese[59] was used. It consists of eight items from the Japanese Critical Thinking Scale by Hirooka, Motoyoshi, Ogawa, and Saito [60] three items drawn from the California Critical Thinking Disposition Inventory (CCTDI; Facione & Facione, 1992), [39] and four new items. They focus on assessing five components of critical thinking attitude: logical approach, inquisitiveness, objectivity, reliance on evidence, and thoughtfulness. The response scale had five points (1:Disagree – 5:Agree) (15 items, Cronbach α=.92).

2.2.4. Source Conflict vs. Source Ambiguity

The respondents were then required to read two experts' opinions about radiation risk. We wrote two opinion pieces (750 Japanese characters) that represented two opposing views about the risk of food radiation: two emphasized a risk to human health (Pro1 and Pro2) and the other two deemphasized it (Con1 and Con2). All respondents were exposed to all four opinion pieces. However, in the conflict condition (*n*=895), they read two pro-pieces attributed to one expert (Pro1 + Pro2) and two con-pieces attributed to the other expert (Con1+Con2); in the ambiguity condition (*n*=905), they read one pro-piece and one con-piece attributed to one expert (Pro1+Con2) and the other pro-piece and the other con-piece attributed to the other expert (Con1+Pro2).

The two opinion sources were successively displayed with a picture of each (approximately 60 year old male university professor). The presentation order was counterbalanced. The interface prevented the respondents from going to the next page until at least two minutes had passed on each page, ensuring that the participants spent sufficient reading time. Immediately after both information sources were presented, the respondents were asked a manipulation check item, whether they thought one source emphasized, but the other de-emphasized, the radiation risk, or both sources said there is some evidence for both risk and safety.

Finally, all participants read three government posters about radioactive contamination risk. This type of mixture of information sources – the simultaneous presence of expert opinions and government's official messages – is common in the contemporary information environment; the government posters also served as a reminder of the institutional communication and a debriefing statement.

2.2.5. Risk Perception, Risk Communication, and Perceived Risk Opinion Distribution

After the government posters, the main dependent variables and perceived risk opinion distribution were measured. First, the respondents were asked how they wished to communicate the radiation risk to (a) their partner and (b) an acquaintance of the same gender and generation whose opinion about radiation risks they do not know. They were given five options (1=Not dangerous; 2=Not dangerous, but there are pros and cons;

3=Cannot decide because there are pros and cons; 4=Dangerous, but there are pros and cons; 5=Dangerous).

Second, they were asked the same questions about radiation risk on a five-point scale (1=Not dangerous; 2=More not dangerous than dangerous; 3=Scientifically uncertain and hard to tell, or I don't know; 4=More dangerous than not dangerous; 5=Dangerous).

Finally, perceived risk opinion distribution (PROD) was measured. Each respondent was asked to report his or her perception of how risk opinions were distributed. Respondents were given the same five options that indicate the degrees of risk as above from "Not dangerous" to "Dangerous," and asked to estimate the number of people out of 10 who would choose each of the five options. It was programmed so that the five numbers had to sum to 10. We assigned a risk value to each option (i.e., "Dangerous" = 5, "Not dangerous" = 1), and computed the mean and standard deviation of each respondent's perceived opinion distribution using their estimated frequencies over these five options. For instance, suppose that a respondent estimated that one out of 10 would choose "Dangerous" (i.e., risk value = 5), one out of 10 would choose "Dangerous, but there are pros and cons" (= 4), two would choose "Cannot decide because there are pros and cons" (= 3), three would choose "Not dangerous, but there are pros and cons" (= 2), and three would choose "Not dangerous" (= 1). Then, the mean and standard deviation of this perceived frequency distribution were computed using the usual formulae. In this example, the perceived mean of the respondent's PROD would be 2.4, and the perceived standard deviation, approximately 1.35.

3. Results

3.1. Preliminary Analyses

We checked if the respondents accurately perceived the conflictual condition as such by examining how many selected the option that one source emphasized, but the other deemphasized, the radiation risk. The manipulation was successful. A majority (52.5%) selected this option in the conflict condition, but a minority (24.1%) selected it in the ambiguity condition. The two conditions differed significantly, $X^2(1) = 153.98$, p. < .0001.

3.2. Main Analyses

3.2.1. Risk Perception

We first examined whether risk perceptions changed from before to after the information presentation. As expected, there was a small, but significant change: risk perceptions were somewhat lower after, *M* = 3.23 (*SD* = 1.05), than before, *M* = 3.46 (*SD* = .99), the information presentation. A repeated measures Analysis of Variance with information condition (conflict vs. ambiguity) confirmed that this change was significant, Wilks' Λ = .935, $F(1, 1798) = 124.38$, *p.* < .001. However, there was no effect of condition, $F < 1.0$.

To investigate the dynamics of risk perception, we fit a linear regression model to predict post risk perception. We included the following control variables: gender, age, educational level, area (affected area vs. Tokyo), and condition (conflict vs. ambiguity). Table I reports the means and standard deviations of the relevant variables as well as their correlations. In addition, we standardized the following variables and included them as predictors: pre risk perceptions, perceived mean, perceived SD, critical thinking attitude, scientific literacy, nuclear radiation knowledge, and media literacy. We finally computed the following interaction effects by multiplying the relevant standardized predictors: perceived mean x perceived SD, pre risk perception x critical thinking, pre risk perception x scientific literacy, pre risk perception x nuclear radiation knowledge, and pre risk perception x media literacy. See Table II for the model and the standardized regression coefficients.

Aside from the expected effect of pre risk perception, older respondents and those who were living close to the Fukushima disaster saw a greater radiation risk. In addition, as hypothesized (H1), mean of the perceived risk opinion distribution (PROD) positively predicted post risk perception, and this effect was negatively moderated by standard deviation of the PROD (H3; see Fig. 3, which contrasts the pattern of interaction for risk perception and communication). Contrary to H2, however, there was a negative main effect of standard deviation. Perception of a wide distribution of risk opinions, *per se*, does not seem to increase risk perception, though a tight distribution strengthens the effect of descriptive norm of risk.

The effect of condition (conflict vs. ambiguity) was not significant, providing no support for H4. However, it is possible that people’s response to this manipulation may be moderated by more complex processes. Further research is needed.

As predicted, general scientific literacy (H5.2), specific nuclear knowledge (H5.3), and media literacy (H5.4) positively moderated the effect of pre risk perception on post risk perception, suggesting that those who are generally scientifically literate, knowledgeable about the specific risk issue, and media literate tend to maintain their risk perception when faced with diverse risk information (see Fig. 5, 6, & 7). Nonetheless, there was no effect of critical thinking attitudes in this analysis. Critical thinking attitudes *per se* do not appear to stabilize risk perception.

3.2.2. *Risk Communication*

We first explored if the level of risk the respondents said they would communicate differs as a function of the addressee, i.e., their partners or acquaintances. Communications were riskier when they were addressed to their partners, M = 2.95, SD = 1.12, than when addressed to their acquaintances, M = 2.87, SD = 1.12. This was confirmed by a repeated measures ANOVA with information condition as a between-participant factor and addressee as a within-participant factor. The main effect of addressee was significant, Wilks's Λ = .98, $F(1,1798) = 33.14$, $p. < .001$. There appeared to be a general tendency to "tone down" the implied level of risk when talking to an acquaintance than when talking to one's partner, suggesting that risk may be amplified more within close social circles than through relatively distant social ties. When people are communicating with acquaintances whose risk perceptions are unknown to them as they were asked to imagine in the present study, they may present generally neutral risk attitudes to avoid the social risk of disputes or embarrassment. This replicated earlier research by Kusumi [47]. Nonetheless, the two types of communications were highly correlated, $r = .859$, $p. < .001$, and therefore averaged to construct an overall risk talk measure.

We then subjected the risk talk measure to an analysis analogous to that for risk perception, using the same set of predictors. Table II reports the relevant statistics. In terms of the control variables, it is interesting to note that, unlike risk perception, gender had an effect – men were more likely to talk up a risk than women. As well, the higher the level of education, the more likely the talk emphasized risk. Although in line with H3, mean and standard deviation of PROD interacted to predict risk talk (see Fig. 3), the pattern of this interaction differed somewhat from that for risk perception.

Again, there was no main effect of condition, unsupportive of H4. The moderating effects of risk literacy were again observed. In line with H5.1, H5.2, and H5.4, those who have critical thinking attitudes, higher general scientific literacy, and greater media literacy tend to communicate risk information in line with their preformed risk perception (Fig. 4, 5, and 7). However, somewhat differently from risk perception, specific nuclear knowledge did not moderate the effect of pre risk perception on risk talk (contra H5.3).

4. Discussion

Within the context of the Fukushima Daiichi Nuclear Disaster, the present study examined perceptions about nuclear radiation risk and risk talk, namely, interpersonal communications about the risk. After respondents were asked about their perception of risk, the identical risk information was presented in two different formats – conflictual or ambiguous – in an internet media-like style, and the respondents were again asked about their risk perception and how they would interpersonally communicate the risk to others. Given the citizens' perceptions of the information environment about the risk and the media information to which they were exposed during the experiment, how would they perceive and communicate the risk issue of a significant magnitude? The experimental situation – reading complex information online – resembled the condition in which the residents of the Fukushima area and the Tokyo metropolitan area found themselves.

4.1. Information Environment about Risk

In line with our expectations, the respondents' risk perception and communication were affected by their perceptions of the risk information environment, namely, perceived distribution of risk opinions. Those who thought the average citizen would regard the risk as high tended to hold their risk perception at a high level (H1), and this tendency was particularly strong when they thought the public risk opinion was consensual (i.e., low standard deviation of perceived risk opinion distribution; H3). Nonetheless, there was no support for the hypothesis that perceived risk opinion variability itself (H2) or the pattern of media presentation of risk information (H4; conflictual vs. ambiguous) can exacerbate risk perception and risk talk. Despite this lack of support for H2 and H4, these aspects of the information environment may affect risk perception and communication interactively with other individual characteristics. Indeed, our additional investigation has pointed to a more complex effects involving the media presentation style; however, we are not including this aspect of the investigation in this report.

It is interesting to note that the pattern of interaction effect between a perceived average risk opinion (PROD mean) and perceived risk opinion consensuality (PROD SD) was somewhat different for risk perception and for risk talk. For risk perception, it is when the perceived average opinion was consensually risky, the respondents' own risk perception was also risky, but otherwise, the respondents' risk perceptions were relatively neutral. However, for risk communication, it was the combination of low perceived risk opinion and high consensus, as well as the combination of high perceived risk opinion and low consensus that particularly lowered the risk communication (Fig. 3). This latter case seems to imply that people tend to down play the risk in their communication when they think there are diverse opinions in the community, possibly tailoring their communication[61] in case their communication partner regards the risk to be relatively low. We will discuss this possibility in greater detail later.

4.2. Responses to the Information Presentation as a function of Risk Literacy and Critical Thinking Attitudes

In this section, we discuss the participants' responses to the presentation of risk information in the experiment. We hypothesized that higher risk literacy and greater critical thinking attitudes tend to stabilize risk perception and to strengthen the tendency to communicate their risk opinions more clearly. Our hypotheses were generally supported with some exceptions.

4.2.1. Risk perception

In response to the exposure to media communication, the respondents shifted their perception downwards to a less risky level on the average, but the extent to which they maintained their risk perception differed as a function of their risk literacy and critical thinking attitudes. Generally speaking, those respondents who regarded themselves as more risk literate – high levels of general scientific literacy, specific scientific literacy, and media literacy – tended to maintain their pre-exposure risk perceptions (H5.2, H5.3, and H5.4). As hypothesized, these risk literacies appear to stabilize risk perception because those who are more risk literate are likely to have greater confidence in their pre-existing risk perceptions. Media literacy too had an interactive effect in line with the hypothesis.

It appears, however, critical thinking attitudes did not affect risk perception stability (contra H5.1). Although we surmised that critical thinkers would have formulated their risk perception about the familiar risk issue and would maintain their pre-existing risk perception, this was not the case. This interpretation seems appropriate in the context of the Fukushima disaster. Because of the unprecedented gravity and magnitude of this nuclear disaster, many Japanese were anxious about the health risk implications with approximately 70% of the residents in the disaster affected and the Tokyo metropolitan areas expressing concerns about negative radiation effects on health.[47] Furthermore, many people appear not to have placed much trust in the government communication because it overemphasized the safety despite the widespread perception of nuclear risk. For this reason, a majority of the residents was actively engaging in information search and collection at multiple information sites following the disaster.[47] Not only those with high levels of critical thinking attitudes, but also those with lower levels of critical thinking attitudes may have been critically evaluating information and thus have consolidated their risk perceptions.

4.2.2. Risk Talk

When it comes to risk talk, the pattern was somewhat more complex. First of all, risk literacy appears to have a similarly stabilizing effect on risk talk – those with high critical thinking attitudes, general scientific literacy, and media literacy tend to communicate their pre-exposure risk perception (H5.1, H5.2, and H5.4). It is intriguing that critical thinking attitudes tend to increase the tendency to express their pre-existing risk perceptions more directly even though the same critical thinking attitudes did not show an effect to stabilize risk perceptions. It may be that critical thinkers have greater confidence in expressing their risk perceptions. The tendency to maintain one's risk perception and the tendency to communicate one's risk perception may be distinctive processes. Second, although specific scientific literacy (i.e., specific knowledge about nuclear radiation) had an effect of stabilizing risk perception, it does not seem to have the effect of strengthening the tendency to express one's risk perception in risk communication.

4.2.3. Contrasting risk perception and risk talk.

It is interesting to note that, despite the general similarity in the patterns of findings about risk perception and risk talk, there were some subtle differences. Before further discussing these differences, it is important to remind ourselves that these differences may be due to chance. For instance, although the effects of critical thinking attitudes (H4.1) and specific scientific literacy (H4.3) were different between risk perception and communication (H4.1 was supported for communication, but not for perception; H4.3 was supported for perception, but not for communication), these may be due to chance. These ideas need to be further examined in future research.

Nonetheless, it may still be instructive to consider possible reasons why the pattern of findings for *interpersonal* communication of risk does not exactly parallel that for *personal* perceptions of risk. Generally, interpersonal communications of risk appear to be more sensitive to the perception of the information environment. Perceived variability (or consensuality) of risk opinions seems to have a more nuanced effect on risk communication than on risk perception. Lesser consensus in risk opinion would mean that there are always people who do not believe the situation is risky – risk communications seem to be tailored to these possibilities, whereas risk perceptions do not seem to be.

One reason for interpersonal communications' sensitivity to the information environment is that people tend to tailor their communications to their potential audience (for a general review, see e.g.,Kashima & Lan[(61)]; Krauss & Fussell[(62)]). People can flexibly tone down or play up their message depending on the opinions that they think their audience holds (e.g., Clark & Kashima[(63)]; Lyons & Kashima[(64)]). Interpersonal communications about risk may also be modified as a function of the perceived distributions of risk opinions in the general population and the presentation of risk information in the media, especially when the communicators do not know what the audience's risk opinions are. Whatever may be the cause of such differences, interpersonal communications can have a significant impact on the societal responses to risk events via the spread of risk information through social networks. This is probably the most significant difference between private perceptions and interpersonal communications of risk.

4.3. Context of the Research and its Likely Impact on the Findings

The present pattern of findings needs to be contextualized in the particular circumstances of the Fukushima Daiichi Nuclear Disaster. First, risk literacy such as general scientific literacy may have particularly strong effects for this type of risk issue in stabilizing risk perceptions and engaging in risk communications. As we noted earlier, there was a great deal of uncertainty after the Fukushima incident. A large proportion of the Japanese population continued to be highly concerned about the radiation risk. Nuclear radiation risk perceptions persist presumably because nuclear radiations are invisible, and their effects are slow emerging.[47] In these circumstances, those who think they are knowledgeable about science may be more confident and outspoken than those who think they aren't.

Furthermore, media literacy may have played a particularly significant role in the current experiment. On one hand, although the information environment was globally polarized, citizens may have been locally exposed to a one-sided online information source. In particular, the government communications emphasized the safety of agricultural products,[51] but non-governmental sources often emphasized the danger of nuclear radiation, which resonated with the popular risk opinions[47] and those who shared risk opinions tended to follow each other in social media such as Twitter,[65] suggesting that respondents may have been more familiar with a homogeneous, rather than heterogeneous, local information environment. On the other hand, the current experiment was designed to present mixed information, albeit in different forms – ambiguous or conflicting. This experimental design may have presented many respondents with the internet information source that they were not familiar with. Consequently, those who were literate about media might have been particularly more confident in their risk perceptions and in expressing their views after being exposed to the ambiguous or conflicting online sources. Thus, the interaction of the information environment – globally heterogeneous, but locally homogeneous – and the experimental information source – locally heterogeneous – may have amplified the effect of media literacy.

All in all, risk literate and critically thinking individuals appear to act as a stable source of communicative influences within social networks in the current context. These individuals hold their risk opinions stably in the face of conflicting or ambiguous information and communicate their views more clearly to others. As a result, they may have relatively large cumulative effects on the risk opinion dynamics by potentially influencing less literate and less critically thinking others in line with their views, creating the locally homogeneous information environment within their social networks, and further polarizing the public opinions about the nuclear radiation risk in the aftermath of the Fukushima Daiichi Disaster.

4.4 Limitations of the Current Study and Concluding Comments

Although the current study has provided insights into risk perception and communication after a uniquely catastrophic risk event, i.e., the Fukushima Daiichi Nuclear Disaster, its limitations also need to be acknowledged. First, the sample of the study was a relatively highly educated segment of the population, i.e., those who have completed at least two years post-secondary education. This was because the research material contained complex and technical information and we hoped to ensure that the respondents could comprehend this information without too many difficulties, so that the study itself would not disengage the respondents. Nonetheless, this may have restricted our ability to investigate a wider range of risk literacy and critical thinking attitudes that would exist in the population. Further research is necessary to generalize our findings to broader populations. Second, the current study used a single item measure of risk perception before and after the presentation of media information. Although this is often done (e.g., Siegrist & Cvetkovich[65]) and we chose this method to reduce the length of the study, future research should make use of multiple item measures of risk perceptions. Third, the measurement used to examine risk talk was contrived and rather limited in scope. Again, to reduce the length of the study, we used rating scales and only a limited number of audience (partner and acquaintance); however, the current method precluded us from investigating how often people spontaneously engage in risk talks in what social contexts. Further investigations are necessary to deepen our understanding of the citizens' communicative engagement with risk information.

All in all, risk perceptions and communications are dynamically maintained and transformed by the interaction of the information environment and the individual risk literacy. Although both risk perception and risk communication are sensitive to the perception of the information environment about risk, their responsiveness critically depends on the risk literacy of the citizens. To gauge societal responses to risk events, it is imperative to investigate the interplay between the citizenry's risk preparedness in the form of risk literacy and the contour of the information environment in the contemporary risk society.

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Table I Means and SDs and Intercorrelations on measures

Measure		*SD*	Gender	Age	Education	Location	PRP	PROD Mean	PROD SD	CTA	GSL	SSL	Media literacy	post risk
Gender(1= M; 2 = F)	1.49	.50												
Age	43.41	7.14	-.33**											
Education	1.76	.58	-.41**	.12**										
Location	.33	.47	-.01	-.14**	-.13**									
Pre Risk Perception (PRP)	3.46	.99	.08**	-.03	-.03	-.04								
Perceived Descriptively Normative Risk Perception (PROD Mean)	3.77	.67	.04	-.02	-.02	-.01	.28**							
Perceived Variability in Risk Perception (PROD SD)	.32	.11	-.01	.00	.02	-.04	-.12**	-.33**						
Critical Thinking Attitudes (CTA)	3.61	.59	-.09**	.10**	.13**	.00	.06*	.04	.03					
General Scientific Literacy (GSL)	.69	.25	-.06*	.11**	.13**	-.04	.01	.00	.09**	.27**				
Specific Scientific Literacy (SSL; knowledge about	2.3	.5	-.11	.0	.15*	.06	-.0	-.0	.13	.25*	.24*			

nuclear radiation)	6	3	**	5*	*	*	5*	6*	**	*	*			
Media literacy	3.57	.70	-.14**	.10**	.11**	.04	.14**	.10**	.00	.39**	.1**	.23**		
Post risk	3.23	1.05	.01	.03	.01	.00	.63**	.32**	-.18**	.08**	-.01	-.04	.19**	
Comm risk	2.91	1.05	-.06*	.04	.06*	.00	.42**	.17**	-.09**	.00	-.04	-.02	.10**	.53**

*Note *p<05, p<.01** (N=1800).* Education (1 = 2 year post-Secondary school; 2 = 4 year University; 3 = Masters or higher); Location (0 = Tokyo area; 1 = Damaged area)

PROD=Perceived Risk Opinion Distribution

Table II. Regression Analyses for Risk Perception and Risk Communication

Predictor	Post Risk Perception			Risk Communication		
	β	pr	Tolerance	β	pr	Tolerance
Gender (1= M; 2 = F)	-.02	-.02	.72	-.06*	-.05	.72
Age	.04*	.04	.85	.03	.03	.85
Education	.02	.02	.79	.05*	.05	.79
Location	.04*	.04	.94	.03	.03	.94
Pre Risk Perception (PRP)	.53**	.49	.85	.37**	.36	.85
PROD mean (M; H1)	**.11****	**.08**	**.64**	**.02**	**.02**	**.64**
PROD SD (SD; H2)	**-.05****	**-.04**	**.87**	**-.00**	**-.00**	**.87**
M x SD (H3)	**-.08****	**-.07**	**.70**	**-.11****	**-.09**	**.70**
Condition (H4)	**.02**	**.02**	**.99**	**.01**	**.01**	**.99**
Critical Thinking Attitudes (CTA)	.01	.01	.77	-.05*	-.05	.77

General Scientific literacy (GSL)	-.03	-.03	.87	-.05*	-.05	.87
Specific Scientific literacy (SSL)	-.03	-.02	.85	-.00	-.00	.85
Media Literacy (ML)	.09**	.08	.79	.04	.04	.79
PRP x CTA (H5.1)	**.01**	**.01**	**.76**	**.07****	**.06**	**.76**
PRP x GSL (H5.2)	**.06****	**.06**	**.91**	**.05***	**.04**	**.91**
PRP x SSL (H5.3)	**.09****	**.08**	**.87**	**.03**	**.03**	**.87**
PRP x ML (H5.4)	**.10****	**.09**	**.76**	**.05***	**.05**	**.76**
R^2		.47***			.22***	
F(17,1782)		91.80			29.52	

Note: Education (1 = 2 year post-Secondary school; 2 = 4 year University; 3 = Masters or higher); Location (0 = Tokyo area; 1 = Damaged area); PROD = Perceived Risk Opinion Distribution; Condition (-1 = Ambiguous; 1 = Conflict); SSL = knowledge about nuclear radiation. B = standardized regression coefficient; pr = part correlation. The effects relevant for the hypotheses are bolded, and the hypothesis number relevant for each effect is listed as in H1, H2, etc.; *** p. < .001, ** p. < .01, * p. < .05.

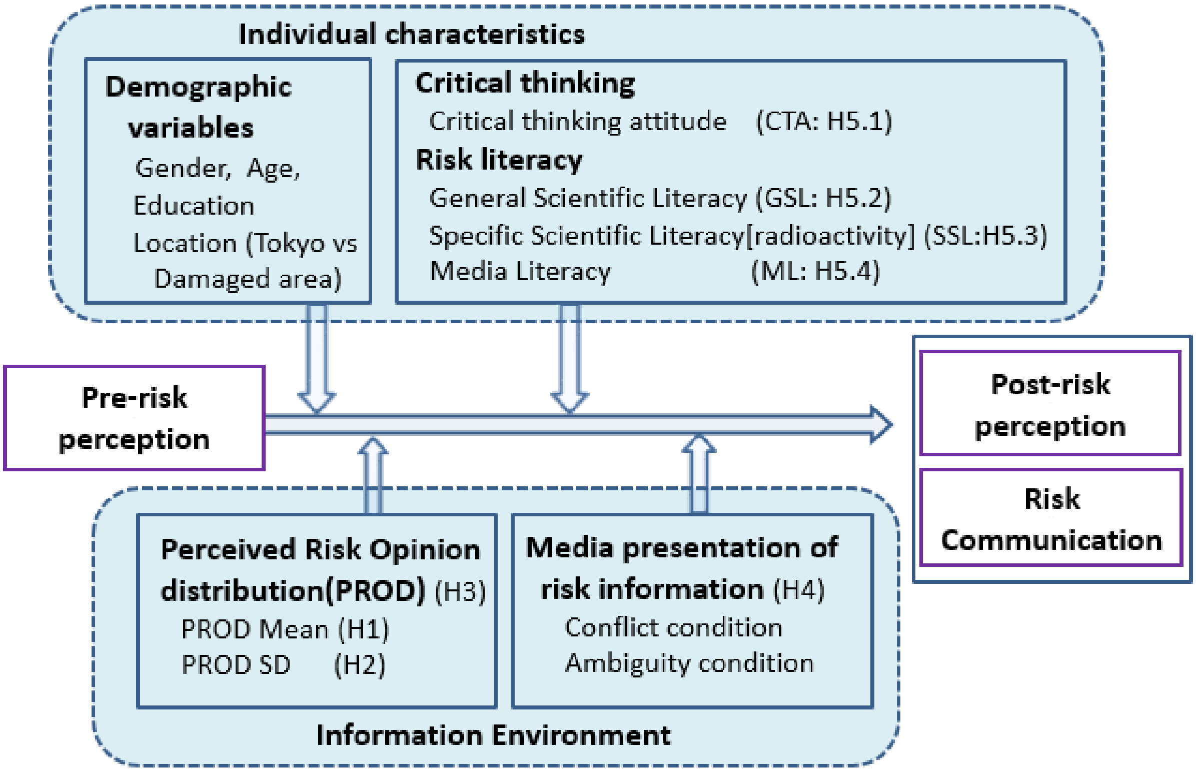

Fig. 1. Conceptual framework of determinants of post-risk perception and risk talk in the case of Fukushima Daiichi nuclear radiation risk

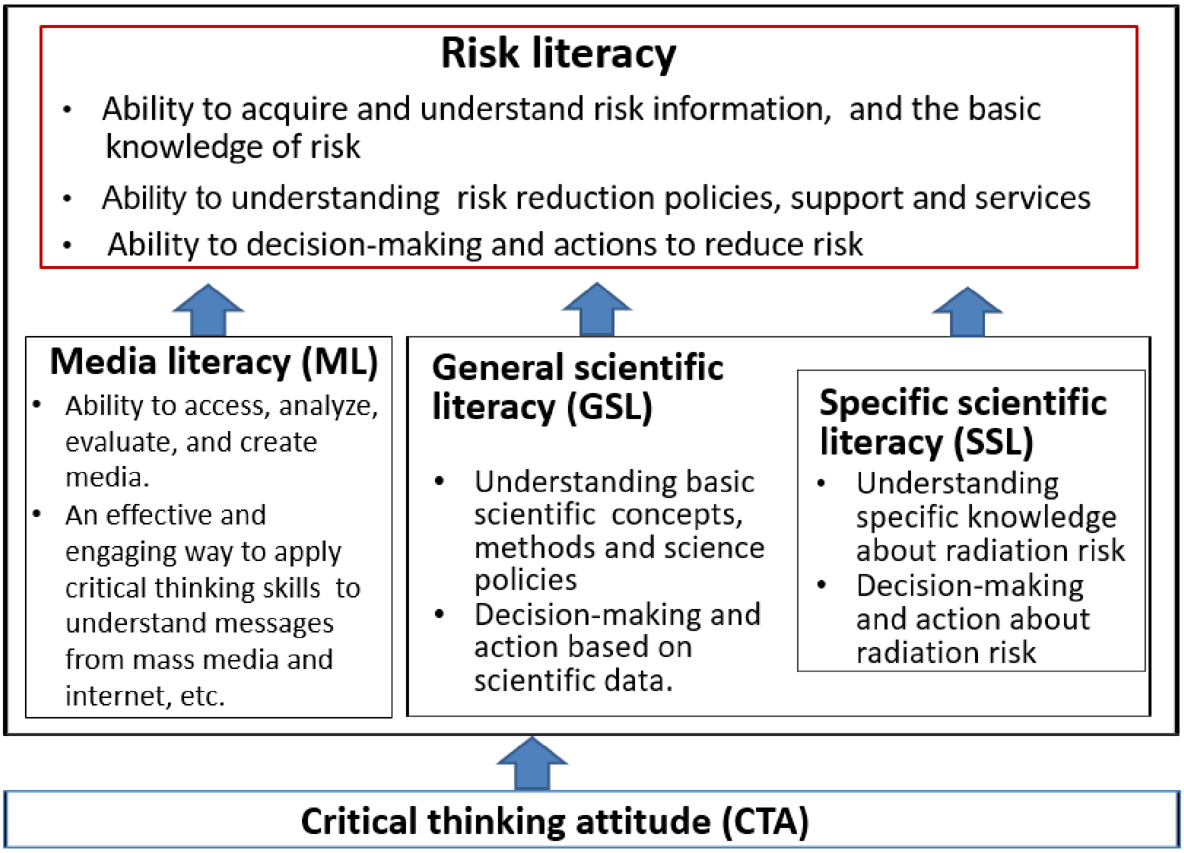

Fig. 2. Structure of risk literacy and critical thinking attitudes

Risk Perception **Risk Communication**

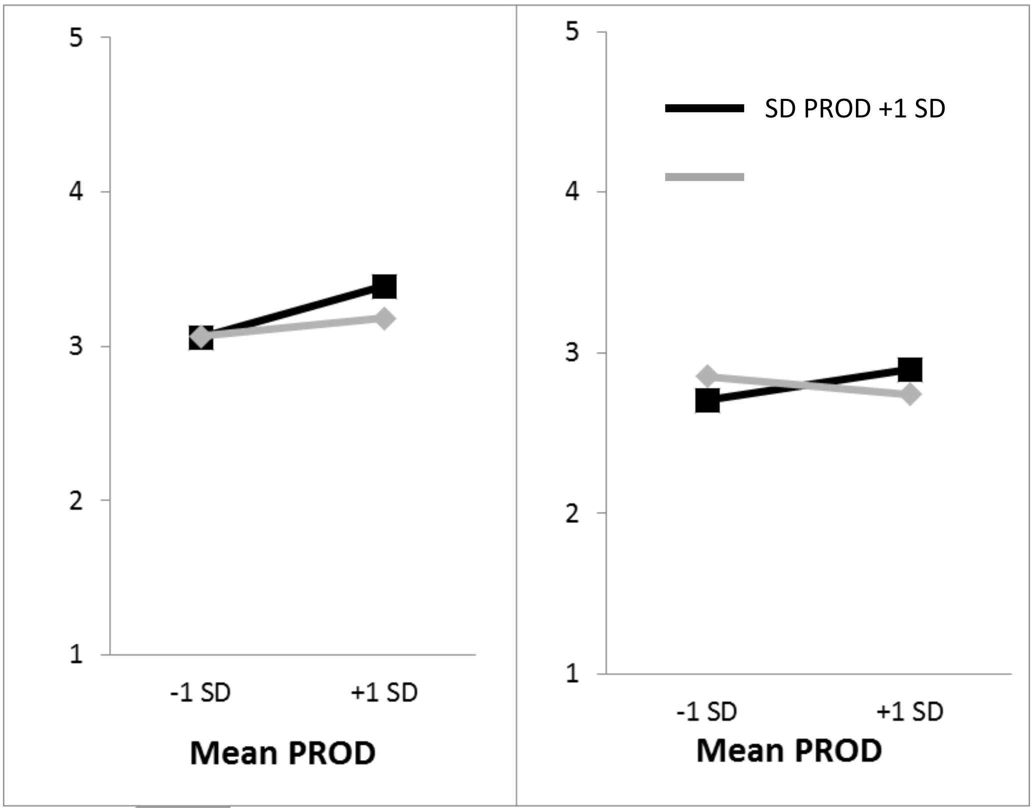

Fig. 3. Mean PROD (Perceived Risk Opinion Distribution) x SD PROD Interaction Effect

Risk Communication

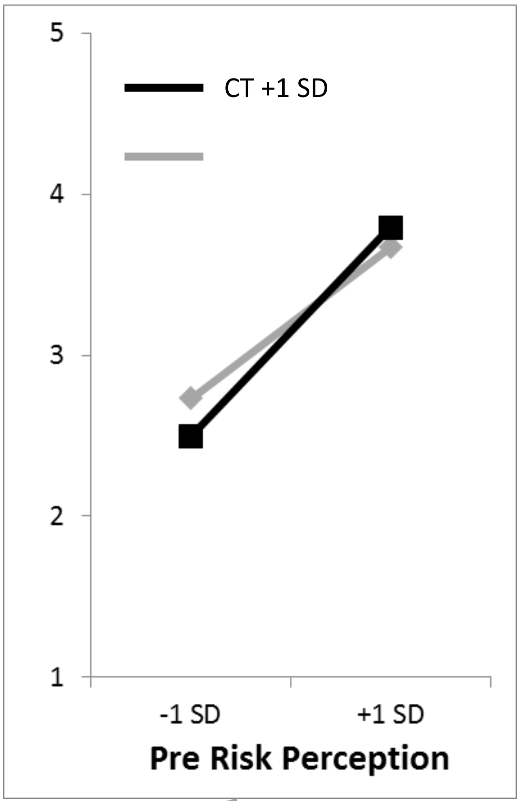

Fig. 4. Pre Risk Perception x Critical Thinking Attitude Interaction

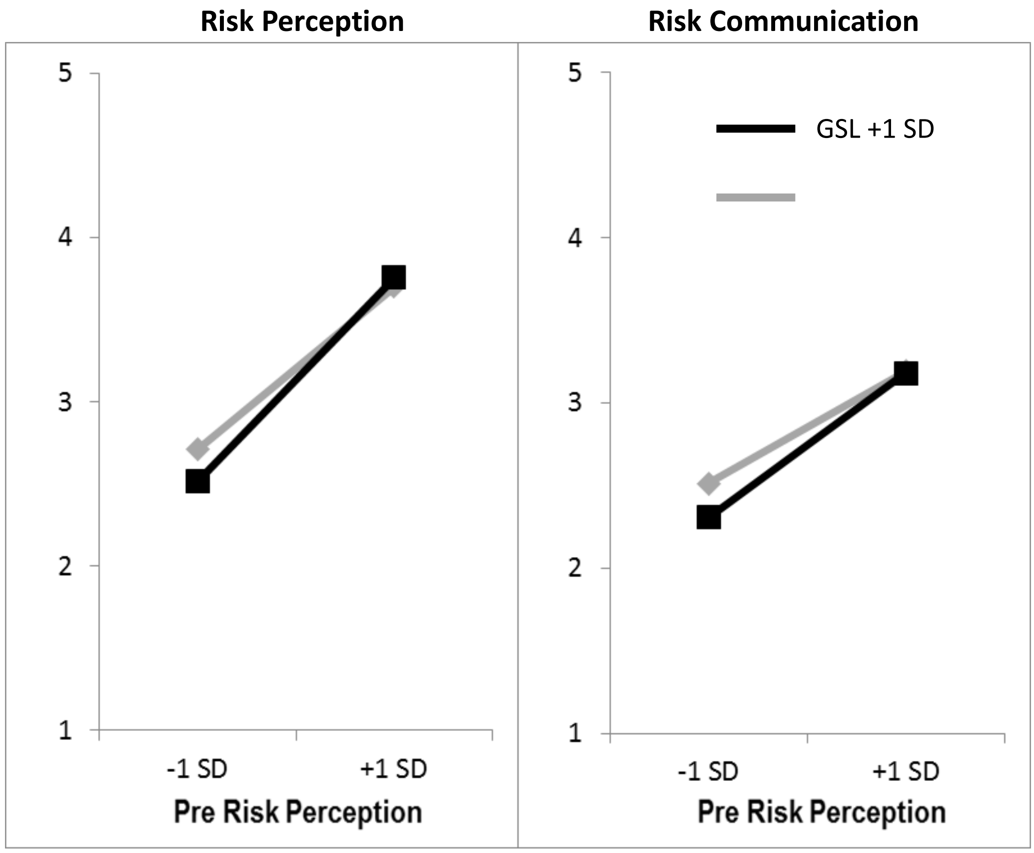

Fig. 5. Pre Risk Perception x General Scientific Literacy (GSL) Interaction

Risk Perception

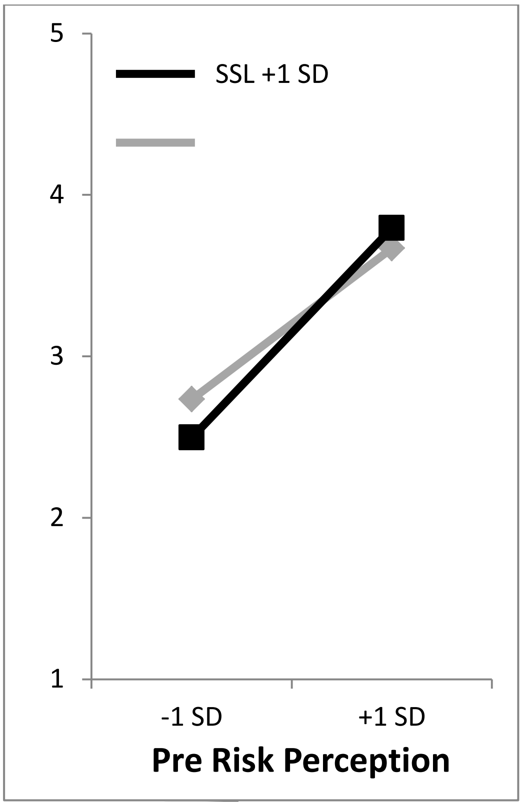

Fig. 6. Pre Risk Perception x Specific Scientific Literacy (SSL) Interaction

Risk Perception **Risk Communication**

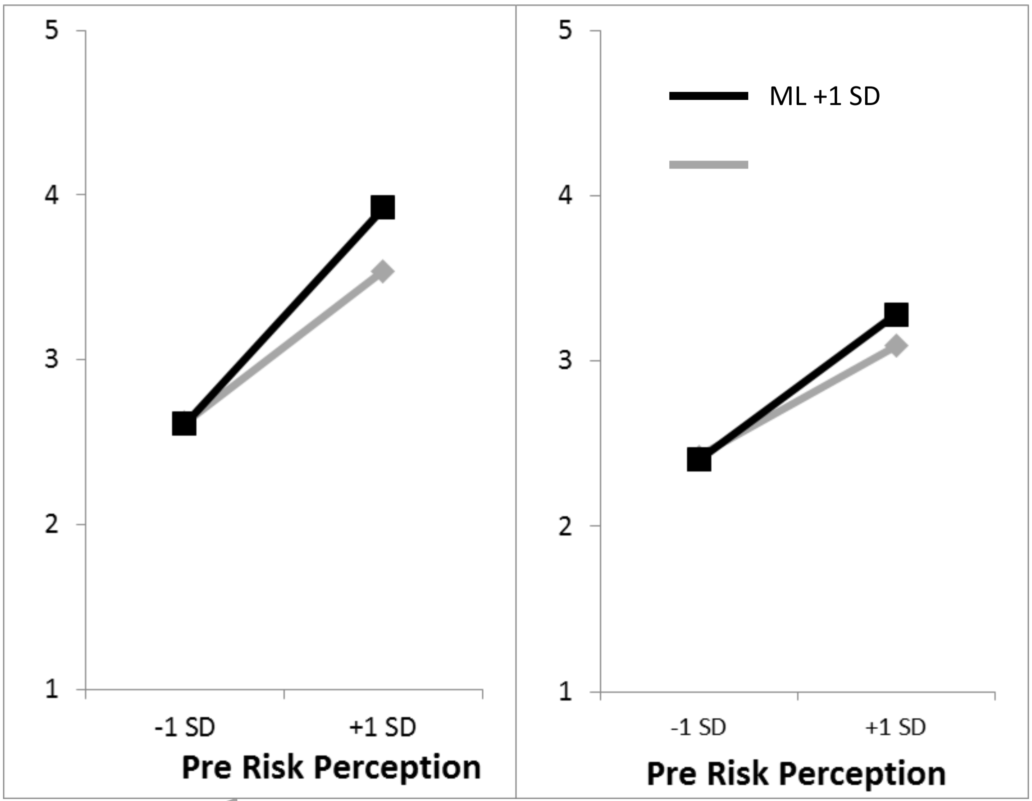

Fig. 7. Pre Risk Perception x Media Literacy (ML) Interaction