Author note: This version of the manuscript contains minor differences to the final version that has been accepted by Wiley for publication in *Risk Analysis: An International Journal*

Assessing the Effects of Narrative, Pictorial, and Graphical Information about Global Population Growth on Risk Perceptions and Support for Mitigation and Prevention Strategies

ABSTRACT

The human population is forecast to increase by 3-4 billion people during this century and many scientists have expressed concerns that this could increase the likelihood of certain adverse events (e.g., climate change, resource shortages). Recent research shows that these concerns are mirrored in public risk perceptions and that these perceptions correlate with a willingness to adopt mitigation behaviors (e.g., reduce resource consumption) and preventative actions (e.g., support actions to limit growth). However, little research has assessed the factors that influence risk perceptions of global population growth (GPG). To contribute to this important goal, this paper presents three studies that examined how risk perceptions of GPG might be influenced by textual-visual representations (like those in media and internet articles) of the potential effects of GPG. Study 1 found that a textual-narrative which highlighted the potential negative (cf. positive) consequences of GPG led to higher perceived risk and greater willingness to adopt mitigation behaviors, but not to support preventative actions. Notably, the influence of the narratives on perceived risk was largely moderated by the participant's prior knowledge and perceptions of GPG. Contrary to expectations, Studies 2 and 3 revealed, respectively, that photographs depicting GPG-related imagery and graphs depicting GPG rates had no significant effect on the perceived risk of GPG or the willingness to embrace mitigation or preventative actions. However, Study 3 found that individuals with higher 'graph literacy' perceived GPG as a higher risk and were more willing to adopt mitigation behaviors and support preventative actions.

KEYWORDS: Decision making; population growth; risk perception, risk communication

1. INTRODUCTION

The global human population has now reached 7.5 billion and is forecast to exceed 11 billion before the year 2100.[1] Based on theory, statistical projections and empirical evidence, many scholars and commentators have expressed concerns that this global population growth (GPG) will lead to increased pressures on global resources, the natural environment and socioeconomic systems and, therefore, will increase the likelihood of a range of adverse events such as climate change, geopolitical instabilities, species extinctions and loss of ecosystems.[2-9] An inference that can be drawn from these concerns is that GPG is likely to make it much harder for humanity to achieve high-level aspirations, such as ending poverty and achieving economic prosperity for all while protecting the natural environment.[10] Several scholars and commentators have argued that the likelihood of achieving sustainable development aspirations will be increased if concerted efforts are made by individuals, organizations and governments to effectively manage the impacts of the GPG that is forecast to take place during this century.[8,11-14]

Recent research shows that the concerns held by academics and commentators about GPG are mirrored in public risk perceptions. Specifically, GPG is perceived as a moderate-to-high risk event and these risk perceptions positively correlated with a willingness to adopt mitigation behaviors (e.g., reduce resource consumption) and preventative actions (e.g., support action to further slow population growth).[15] Hence, an awareness of GPG and the way that it may influence the likelihood of adverse events represents one mechanism that could motivate important behavioral changes in the coming years and decades. However, there is little empirical evidence to show what influences individual's risk perceptions of GPG.

As demonstrated by the extensive body of evidence in the field of risk communication research, risk perceptions and risk behaviors are often significantly influenced by the information that individuals receive about the risks and benefits associated with particular

objects, behaviors or events.[16-18] For example, in the 1990's inaccurate media reports about the risk of thromboembolism from taking the contraceptive pill led thousands of British women to stop taking the pill and resulted in a wave of unwanted pregnancies.[19] Similarly, risk perceptions of climate change have been found to vary based on the way that the related scientific data is presented and described.[20-22] Hence, evidence from risk communication research points towards the potential for relationships between the information that individuals receive about GPG, their level of concern about its potential effects and their willingness to adopt and to support mitigation actions. While general levels of public concern about GPG have been found to correlate with the *quantity* of media articles about GPG,[23] there remains a dearth of research that has assessed the extent to which the different *content* in GPG articles influences perceived risk.

1.1. The Communication of Global Population Growth

Information about GPG is now readily available to the public through various mediums such as magazines, books, newspaper articles and the internet. These sources typically present a textual narrative about the potential effects of GPG and commonly use visual aids such as photographic images to support arguments and graphs to illustrate key data such as projected population levels throughout this century.[e.g., 13,24-28] The nature of the narratives can range from describing GPG as a primary driver of a wide range of adverse outcomes for humanity and the natural environment, to describing it as positive affirmation of humanity's success and as a provider of greater opportunities for humans to live sustainably through increased innovation, interconnectivity and economies of scale. The photographic images that are often used in these articles tend to depict historical or extant circumstances that are congruent with the textual narrative. For example, an article that focuses on the professed relationship between increased GPG, resource consumption and environmental damage might use a photographic image of a large area of natural land that has been subject to deforestation or use aerial images of the Earth

where huge areas of rural land have been replaced by heavy industry, solar farms, landfill sites, etc. Conversely, a narrative that argues for the benefits of GPG might feature photographic images depicting people interacting harmoniously, engaging in sustainable practices or sharing the joy of child birth.[for examples, see 26 and 29] How these three commonly used communication formats (text, photos and graphs) might each have an influence on the perceived risk of GPG are, therefore, worthy of further consideration.

1.1.1. Risk Communication and Textual Narratives

Risk communications often feature numerical data regarding the probability of specific adverse outcomes.[30] However, in the absence of quantified probabilities, risk communicators often rely on a narrative that independently conveys qualitative information about risk magnitudes.[31-33] Within these latter narrative forms, forecasters often use reasons, evidence or logic to support their likelihood assessment and research shows that such narratives can significantly influence the recipient's level of perceived risk in a variety of contexts (e.g., health, terrorism, nanotechnology, etc.).[31,34,35] More specifically, evidence suggest that risk perceptions increase when narratives (a) focus mainly on adverse outcomes, even when the narratives are not intended to elicit affective reactions,[36] and (b) contain information about the presence of adversity rather than information about its absence.[37-39] Furthermore, risk perceptions have also been found to decrease in response to narratives that focus solely on the benefits of a particular entity.[40,41] Hence, it would seem reasonable to assume that narratives which use arguments and evidence to convey the view that GPG predominantly increases (decreases) the likelihood of specific adverse outcomes would cause the recipient's risk perceptions to increase (decrease). However, this assumption is worthy of empirical examination given that there is also some evidence which shows that narratives about risk-related issues are not always effective at influencing perceptions and behaviors.[42-44] Examining the influence of GPG narratives on risk perceptions and behaviors is also important

because scholars have often asserted that narratives are a vital factor in influencing and polarizing perceptions of GPG,[13 p.4, 45 p.1591] yet this assertion has not been subject to empirical assessment.

1.1.2. Risk Communication and Photographic Imagery

Several studies have highlighted the important role that affect plays in risk perceptions.[46-49] Specifically, the affective/emotional states that individuals experience or associate with a particular hazard can act as distinct psychological cues regarding the magnitude of the threat posed by the hazard.[50] Research shows that photographic imagery depicting adverse outcomes can elicit negative affective reactions and, thus, increase perceived risk. For example, Keller, Siegrist and Gutscher (2006) found that photographs of a house submerged in water elicited negative affective reactions and higher risk perceptions for flooding.[51] Similarly, Hammond et al. (2004) found that smokers who viewed vivid photographic warning labels on cigarette packets experienced negative affective responses and, subsequently, were more likely to have quit, attempted to quit or reduced smoking three months later.[52] Thus, communications about GPG that include photographic images depicting negative outcomes or events (e.g., human destruction of natural environments, severe overcrowding in public places, etc.) may also increase the perceived risk of the growing human population and could motivate greater willingness to engage in risk management behaviors.

1.1.3. Risk Communication and Graphs

Studies show that graphical displays such as bar charts, line plots and icon arrays can be effective formats for communicating risk-related information in a range of different domains (e.g., health, safety, finance, etc.) and are often capable of influencing perceived risk and the willingness to adopt risk reduction measures.[19,30,53-55] For example, Stone et al. (2017) found that bar charts depicting the risk of exposure to unexploded ammunition during land excavation led to increased fear and influenced support for risk mitigation policies.[56] Dawson et al. (2013)

found that icon arrays helped individuals to understand that the combined use of alcohol and tobacco resulted in a synergistic risk of developing esophageal cancer.[57] Moreover, researchers have also identified that individual differences can exist in graph literacy (i.e., the ability to understand graphically presented information) and that this can influence perceptions and decisions concerning risk.[58,59] Hence, the extant literature points towards the possibility that the graphical displays used in communications about GPG may have the potential to influence perceived risk and the willingness to mitigate the effects of GPG. More specifically, levels of perceived risk may be influenced by graphs that display different projected levels of GPG, with higher (lower) levels of GPG depicted in the graph resulting in higher (lower) levels of perceived risk. In addition, the literature also indicates that these influences might be influenced by an individual's level of graph literacy.

1.2. The Present Research

There is currently no clear consensus in the academic literature as to whether strategies to (a) limit GPG or (b) encourage mitigation behaviors, might prove to be the most effective approach for reducing the likelihood of the adverse events that may be influenced or exacerbated by GPG.[60] However, both approaches imply that people, individually or collectively, must be motivated to pursue these courses of action if the challenges of GPG are to be managed effectively. As illustrated in recent research, higher risk perceptions of GPG are positively correlated with the willingness to support GPG limiting actions and to adopt mitigation behaviors. Hence, there is a clear need to understand what might increase the perceived risk of GPG and, therefore, could motivate risk management actions that may prove to be highly valuable during this century. Unfortunately, there is a dearth of research that has examined the extent to which the information formats that are commonly used in communications about GPG (i.e., text, photographic and graphical displays) influence

perceived risk. The present three studies were conducted to address this knowledge gap and, respectively, to test the following three hypotheses:

Narrative Hypothesis: A narrative that highlights potential adverse (cf. beneficial) consequences of GPG will lead to a higher perceived risk of GPG.

Photographic Imagery Hypothesis: Images that highlight adverse (cf. beneficial) aspects of humanity's impact on the world will lead to a higher perceived risk of GPG.

Graphical Displays Hypothesis: Graphs depicting higher (cf. lower) levels of projected GPG will lead to a higher perceived risk of GPG.

2. METHOD & RESULTS

2.1. Study One

2.1.1. Participants

A sample of 152 participants was recruited via Amazon.com's Mechanical Turk and each participant was paid $1.50.[61,62] An "instructional manipulation check" (IMC) was used to identify inattentive participants.[63] One participant was excluded for failing the IMC, which left a final sample of 151 participants (68 women, 83 men). The final sample's mean age was 34.99 (*SD* = 11.33), all participants were U.S. residents and 83 were educated to degree level or higher. One-hundred-and-nineteen participants were white, twelve were black or African American, nine Asian, eight Hispanic, one Latino and two were of mixed background.

2.1.2. Measures and Procedure

The study was administered online and each participant read the following opening statement: 'There are currently over 7 billion people in the world and the population is growing by approximately 70 million people each year. This means that by the year 2045 there will be more than 9 billion people in the world. Research shows that global population growth presents several significant changes for humanity.' So that participants would not be unduly influenced to perceive GPG positively or negatively at this stage, this opening statement referred only to

extant data and evidence-based projections and did not refer to any potential risks or benefits associated with GPG. As a between-subjects factor, participants were randomly assigned to read either no additional information (control group; $n = 50$), a 196-word statement describing the potential adverse effects of GPG (risk narrative group; $n = 50$) or a 196-word statement describing the potential positive effectives of GPG (benefits narrative group; $n = 51$) (see Appendix for both statements). The risks narrative and the benefits narrative were, respectively, based on the reasons, evidence and logic that is commonly used in written articles about the negative and positive effects of GPG,[for examples see 25,27,29,64] and both statements highlighted the effects of GPG in the same domains (e.g., economic, environmental, etc.).

To measure perceived risk, participants were asked to use an 11-point scale (0 = strongly disagree; 10 = strongly agree [the other numbers on scale were not labelled]) to indicate their agreement with nine statements based on statements used by Dawson and Johnson.[15] The statements referred to the degree to which the participants were concerned that during this century GPG will increase (i) the rate of climate change, (ii) water and food shortages, (iii) energy shortages, (iv) plant and animal extinctions, (v) ecosystem damage, (vi) the number of people killed in man-made and natural disasters, (vii) the number of violent conflicts in the world, (viii) global economic decline and (ix) the risk to humanity. To measure willingness to employ mitigation behaviors and support preventative actions, participants used the same 11-point scale to indicate their agreement with seven statements based on those used by Dawson and Johnson.[15] The four statements used to measure willingness to employ mitigation behaviors asked participants how willing they were to reduce (i) water and food consumption, (ii) travel less using fossil fuels powered transport, (iii) consumption of material good, and (iv) usage of goods/services that are unfriendly to the environment. The three statements used to assess willingness to support preventative actions asked participants to state how willing they were to (i) pay more taxes to fund government projects aimed at reducing

GPG, (ii) vote for a political party that wanted to spend more public money on reducing GPG, and (iii) donate money to a charity that works to reduce GPG. These measures of perceived risk and willingness to practice/support certain behaviors were used because they had demonstrated strong discriminant validity in Dawson and Johnson's study. Specifically, the measures had detected significant differences in the perceived risk and willingness to practice/support certain behaviors between different socio-demographic groups and between those who held different affective reactions to GPG.

Participants were also asked to use an 11-point scale (0 = strongly disagree; 10 = strongly agree) to indicate the extent to which they agreed that the content of the piece of text that they had just read about GPG was consistent with the knowledge and views that they had about GPG before participating in the study (item referred to hereafter as 'narrative consistency'). This question was asked to facilitate a subsequent evaluation of the extent to which prior knowledge and views about GPG might moderate the effect of GPG narratives on perceived risk.

2.1.3. Results

There were no significant differences in the mean age ($F[2, 148] = 0.69$, $p = 0.50$) or the proportion of participants from each gender or education level ($X^2 \leq 3.60$, $df = 2$, $p \geq 0.17$) between the control, risk narrative and benefits narrative conditions.

The nine items used to measure perceived risk were combined to form one scale labeled "overall perceived risk" (Cronbach's $\alpha = 0.94$). The scale mean was 6.51 ($SD = 2.17$) indicating that the whole sample perceived GPG as a moderate-to-high risk event. The four items used to measure willingness to employ mitigation behaviors were combined into one scale labeled "mitigation behaviors" (Cronbach's $\alpha = 0.88$) and this had an overall mean of 5.98 ($SD = 2.38$). The three items used to measure willingness to support preventative actions were combined into a scale labeled "preventative control" (Cronbach's $\alpha = 0.86$) and this had an overall mean

of 4.2 (*SD* = 2.68). Hence, the scales demonstrated high reliability and the mean for overall perceived risk demonstrated some consistency with the mean obtained in Dawson and Johnson's study of U.K. residents (see Table II in the Appendix for mean and median scores on each measure for each condition).[15]

An ANOVA identified that overall perceived risk was significantly different between the three narrative groups, $F(2, 148) = 3.07$, $p = 0.049$. A planned contrast showed that the overall perceived risk for participants in the risk narrative group ($M = 7.12$; $SD = 1.85$) was significantly higher, $t(148) = 2.48$, $p = 0.014$, than for participants in the control group ($M = 6.22$; $SD = 2.13$) and in the benefits narrative group ($M = 6.19$; $SD = 2.41$). Thus, the *Narrative Hypothesis* was supported. Notably, there was no significant difference, $t(99) = 0.07$, $p = 0.946$, between the overall perceived risk in the control group and the benefits narrative groups.

A second ANOVA identified that mitigation behavior was also significantly different between the three narrative groups, $F(2, 148) = 5.04$, $p = 0.008$. A planned contrast showed that the mitigation behavior for participants in the risk narrative group ($M = 6.84$; $SD = 2.06$) was significantly higher, $t(148) = 3.17$, $p = 0.002$, than for participants in the control group ($M = 5.52$; $SD = 2.4$) and in the benefits narrative group ($M = 5.60$; $SD = 2.49$). However, a third ANOVA found that preventative control did not differ significantly, $F(2, 148) = 1.36$, $p = 0.261$, between the control group ($M = 3.86$; $SD = 2.9$), the risk narrative group ($M = 4.7$; $SD = 2.62$) and the benefits narrative group ($M = 4.05$; $SD = 2.51$).

Mean ratings for narrative consistency were 6.70 ($SD = 2.21$) in the control group, 6.28 ($SD = 2.28$) in the risk narrative group and 2.88 ($SD = 2.67$) in the benefits narrative group. An ANOVA revealed a significant difference, $F(2, 148) = 34.74$, $p < 0.001$, for narrative consistency between the three groups. A Tukey's post hoc test showed that there was no significant difference between narrative consistency in the control group and risk group, $p = 0.685$, but narrative consistency in the benefits narrative group was significantly different from

both the control group and risk narrative group, *p*s < 0.001. To assess whether narrative consistency moderated the identified relationship between perceived risk and GPG narratives, a moderation analysis was performed using the SPSS macro PROCESS (the control group data was excluded from this analysis due to the absence of a difference in narrative consistency between this group and the risk narrative group).[65] This analysis identified a significant interaction effect (narrative x consistency), b = -0.829, 95%CI [-1.194,-0.463], t = -4.502, p < 0.001, but no significant independent effects for narrative, b = -0.768, 95%CI [-1.929, 0.393], t = -1.313, p = 0.192, or consistency, b = 0.040, 95%CI [-0.143, 0.223], t = 0.437, p = 0.663, were evident in this model. With respects to the interaction, the analysis showed that when narrative consistency was low, perceived risk was significantly lower in the risk (cf. benefits) narrative group (b = 1.851, 95%CI [0.262, 3.440], t = 2.312, p = 0.023). When narrative consistency was at the mean there was no significant difference in perceived risk between the two narrative groups (b = -0.768, 95%CI [-1.929, 0.393], t = -1.313, p = 0.192). When narrative consistency was high, perceived risk was significantly higher in the risk (cf. benefit) narrative group (b = -3.387, 95%CI [-5.072, -1.702], t = -3.990, p < 0.001. In other words, a participant's prior perceptions of GPG influenced the extent to which the narrative affected his/her risk perceptions. Specifically, the highest (lowest) level of perceived risk, M = 7.79 (M = 4.40), was amongst participants in the risk (benefits) narrative group who specifically reported that the narrative was highly consistent with his/her prior perceptions of the effects of GPG.

2.1.4. Discussion

The results of Study 1 showed that narratives which focus on the potential adverse effects of GPG can raise risk perceptions and increase the willingness to engage in related mitigation behaviors, but not the willingness to support preventative actions. These findings suggest that narratives do play a critical role in influencing people's perceptions of GPG and, if concerns about the adverse effects of GPG are warranted, could be critical in motivating

important mitigation behaviors. This insight seems particularly noteworthy given that, unlike typical GPG communications, the risk narrative in Study 1 was very limited in content (i.e., only 196 words) but still significantly increased perceived risk and the willingness to adopt mitigation actions. Furthermore, unlike some other studies which have shown that risk perceptions are often attenuated by information about benefits,[40,41] risk perceptions among the participants in the benefits narrative group did not differ from risk perceptions in the control group. One explanation for this may be that the benefits narrative generally lacked consistency with *a priori* beliefs about GPG (as reflected in the low 'narrative consistency' score in the benefits group) and, therefore, this line of reasoning and argument lacked sufficient credibility and plausibility to have a significant effect on perceptions.

The results of Study 1 raise two further important points. First, while the risk narrative increased the participant's willingness to adopt mitigation behaviors it did not increase willingness to support preventative actions. A possible explanation for this finding is that preventative actions may involve restricting other people's opportunity to have children and, more generally, implicitly suggest that future human lives will inevitably generate problems. Therefore, such approaches may elicit some degree of negative affect and have limited appeal as 'risk management' strategies.[5] By contrast, mitigation behaviors may represent positive solutions that contribute to important social goals (e.g., reducing carbon emissions to tackle climate change) and imply that current and future humans can behave sustainably.[66] Therefore, such approaches might elicit more positive affect and hold greater appeal. Second, the moderation analysis showed that risk perceptions were heavily driven by the way that the narrative interacted with prior beliefs and, driven much less by the narrative alone. This points towards GPG narratives being a powerful medium for influencing risk perceptions through the 'confirmation bias'; a tendency for individuals to interpret evidence only in ways that are consistent with existing beliefs, expectations or hypotheses.[67] More specifically, the results of

the moderation analysis suggest that specific GPG narratives can bolster existing beliefs and views about the potential effects of GPG, in the same way that an individual's beliefs about any entity (e.g., other nations, professions, religions, etc.) can become reinforced and more extreme when interacting with other people who that hold and express similar beliefs about that entity.[68,69]

2.2. Study Two

2.2.1. Participants

A separate sample of 179 participants was recruited via Mechanical Turk and each participant was paid $1.50. One participant was eliminated for failing the IMC and another for not providing sufficient data. This left a final sample of 177 that consisted of 78 women, 98 men and one of unstated gender. The mean age was 34.32 (*SD* = 9.59), all participants were U.S. residents and 105 were educated to degree level or higher. One-hundred-and-thirty-seven participants were white, twelve were Asian, eleven black or African American, seven Hispanic, two Latino, two Arab, one American Indian and three were of mixed background (two did not state their ethnicity).

2.2.2. Measures and Procedure

The study was administered online and each participant read the following opening statement: 'There are currently over 7 billion people in the world and the population is growing by approximately 70 million people each year. This means that by the year 2045 there will be more than 9 billion people in the world.' As a between-subjects factor, participants were randomly assigned to view either no images (control group; $n = 59$), eight photographic images depicting negative aspects of human actions, living conditions or impacts on the environment (negative images group; $n = 59$) or eight photographic images depicting positive aspects of human actions, living conditions or impacts on the environment (positive images group; $n =$

51). All images were in color and selected to represent those typically used in articles/books on GPG.(for examples see 26,29)

The images in both the 'positive' and 'negative' groups represented the same eight themes and both sets of images were, respectively, presented with the same eight short titles (12 words maximum) that briefly described the theme of each image. For example, one of the images viewed by participants in the negative images group was of the giant Mirny diamond mine in Siberia and featured the title 'People use the Earth's resources'; one of the images viewed by participants in the positive images group was of a farmer hand-picking oranges from a tree on a sunny day and also featured the title 'People use the Earth's resources' (see Figure 1). Table I provides descriptions of all eight images viewed by participants in the positive images group and negative images group and the eight titles used across both sets of eight images.

[Insert Table 1 about here]

[Insert Figure 1 about here]

After participants had viewed each image he/she was required to type one sentence to describe what the image depicted. This requirement was made to ensure that participants engaged with the content of the image rather than just glancing/clicking past it to speed up the participation process. All eight images were presented in a random order.

Perceived risk, willingness to employ mitigation and willingness to support preventative actions were measured using the same statements and 11-point responses scales that were used in Study 1. Participants not in the control group were also asked to use an 11-point scale (0 = strongly disagree; 10 = strongly agree) to indicate the extent to which they agreed that the eight images they had viewed were consistent with the images that would come into their mind when they thought about GPG (item referred to hereafter as 'image consistency').

2.2.3. Results

There were no significant differences in the mean age (F[2, 173] = 1.51, p = 0.22) or the proportion of participants from each gender or education level ($X^2 \leq 2.21$, df = 2, ps $\geq$ 0.33) between the control, negative images and positive images conditions.

As per Study 1, the relevant items were combined to form scales for "overall perceived risk" (Cronbach's α = 0.94; M = 6.63; SD = 2.24), "mitigation behaviors" (Cronbach's α = 0.92; M = 6.10; SD = 2.63) and "preventative control" (Cronbach's α = 0.84; M = 4.71; SD = 2.67) (see Table III in the Appendix for mean and median scores on each measure for each condition). An ANOVA identified that the overall perceived risk for the control group (M = 6.95; SD = 1.93), the negative images group (M = 6.43; SD = 2.49) and the positive images group (M = 6.52; SD = 2.28) did not differ significantly, F(2, 174) = 0.89, p = 0.411. Hence, the *Photographic Imagery Hypothesis* was rejected.

A second ANOVA also showed that the willingness to adopt mitigation behaviors in the control group (M = 6.42; SD = 2.28), the negative images group (M = 6.11; SD = 2.75) and the positive images group (M = 5.77; SD = 2.84) did not differ significantly, F(2, 174) = 0.91, p = 0.405. Similarly, a third ANOVA identified that the willingness to support preventative control in the control group (M = 5.08; SD = 2.50), the negative images group (M = 4.51; SD = 2.77) and the positive images group (M = 4.52; SD = 2.75) did not differ significantly, F(2, 173) = 0.88, p = 0.413. However, a t-test revealed that image consistency in the negative images group (M = 6.68; SD = 2.41) was significantly higher, t(113) = 4.31, p < 0.001, than in the positive images group (M = 4.62; SD = 2.74).[1]

2.2.4. Discussion

The 'negative' images shown to participants in Study 2 had no significant effect on the perceived risk of GPG. This result may appear somewhat surprising given that such images are commonly used to support the risk narratives that are employed in articles and commentaries

that highlight the potential adverse effects of GPG. It is also surprising because participants in Study 2 considered the 'negative' images to be significantly more representative of the imagery that they associate with GPG. Thus, one might have expected, as may have been observed in the risk-narrative condition in Study 1, that the negative images would have elicited a confirmation bias that bolstered extant beliefs about GPG being a cause of future adverse outcomes.

One potential explanation why the negative images in Study 2 did not influence the perceived risk of GPG could be because of the inability of photographic images to depict actual future events. That is, authentic photographic images can only ever depict current or past circumstances or, with a supporting narrative, be presented as a likeliness of what future events may hold. Many individuals may consider these photographic depictions to be representative of comfortable, tolerable or historical circumstances. Thus, in isolation, such images appear to be a less effective medium for convincingly conveying the potential future adverse impacts of GPG and, therefore, may not elicit higher levels of perceived risk. By contrast, risk narratives can depict alternative futures (albeit hypothetical ones) and, more specifically, focus on developing rationales and reasons to convince individuals that continued GPG will present greater levels of risk and adversity than have previously been or are currently being experienced. This explanation for the results from Study 2 seems particularly plausible when it is considered that risk perceptions are evaluations of and responses to potential *future* adverse events.[70]

Another point worthy of consideration is that the positive images typically used in articles/books on GPG tend to feature far less people than the negative images. Arguably, images that only feature a small number of people do not necessarily offer an accurate portrayal of a future in which both extensive GPG could have occurred and the general standard of living could have improved. That is, one might expect positive GPG images to feature both a large

number of people and evidence of successful adaptations (e.g., a densely populated urban area that is well designed and landscaped, with attractive vegetation, modern facilities, clean environment, etc.). Hence, it is possible that the risk perceptions of participants in Study 2 were not attenuated by the positive images (which represent those typically used in articles/books) because the images were not consistent with their own perceptions of what the positive future effects of GPG might be.

2.3. Study Three

2.3.1. Participants

A separate sample of 202 participants was recruited via Mechanical Turk and each participant was paid $1.50. No participants failed the IMC. The sample consisted of 82 women, 120 men, with a mean age of 34.29 (*SD* = 10.02). All participants were U.S. residents and 125 were educated to degree level or higher. One-hundred-and-sixty-three participants were white, fourteen were Asian, seven Hispanic, six black or African American, three Latino, and six were of mixed background (three did not state).

2.3.2. Measures and Procedure

The study was administered online and each participant was randomly allocated to one of four conditions (low; medium; high; all). Participants saw one of four line graphs that each depicted population growth data from the year 1800 to the year 2100. The line-data in all four graphs was identical from the year 1800 to 2012 (based on historical data published by the United States Census Bureau), but varied from 2012 onwards depending on the condition.[71] In the low, medium and high conditions the line-data from 2012 onwards depicted, respectively, only low, median or high GPG projections. In the all condition, the line-data from 2012 onwards depicted the low, median and high GPG projections (all line-data from 2012 onwards was based on population projections published by the United Nations Population Division (UNPD) in 2013).[72] Essentially, the all condition was included as a control condition against

which the influence of the other three graphs could be assessed. The lines in the graphs were not presented in the colors red or green because these colors can be interpreted as negative/danger and positive/safety respectively and, therefore, could have influenced perceived risk.[73,74] Also, the *y*-axis on the graphs started at zero to provide a neutral reference point that can aid graph comprehension.[58] Figure 2 shows an example of the graph used in the all condition.

[Insert Figure 2 about here]

The graphs were preceded by a brief statement that, in the low condition, stated 'The graph below shows how the global human population has changed over time and how it is projected to change in the future. The estimate for the future is based on each woman having, on average, a relatively low number of children. The graph has been compiled using data published by the US Census Bureau and the United Nations Population Division.' The second sentence in the statement was adapted slightly for each condition: participants in the medium and high conditions read the words 'a medium' or 'a relatively high', respectively, instead of 'a relatively low'. Participants in the all condition read a different second sentence: 'The graph shows three different estimates (low, medium, high) for the future based on differences in the average number of children that each woman might have.'

To ensure participants engaged with the content of the graph and processed the depicted data, they were each asked to answer five simple questions about the graph (e.g., 'To the nearest billion, what was the population of the world in 1825?'). However, to obtain a formal measure of the participant's ability to understand graphically presented information, participants were also asked to complete the established Graph Literacy Scale (GLS) developed by Galesic and Garcia-Retamero.[58] The GLS measures the extent to which individuals are capable of understanding graphical data, extracting relevant information from graphs and making

inferences beyond the data depicted in graphs; hence, the GLS facilitated a measure of any relationship between graph literacy and the perceived risk of GPG.

Perceived risk, willingness to employ mitigation behaviors and willingness to support preventative actions were measured as per Studies 1 and 2. Participants were also asked to use an 11-point scale (0 = strongly disagree; 10 = strongly agree) to indicate the extent to which they agreed that the data in the graph they had viewed was consistent with their knowledge about global population growth before taking this survey (item referred to hereafter as 'graph consistency').

2.3.3. Results

There were no significant differences in the mean age (F[3, 198] = 2.36, p = 0.07), or the proportion of participants from each gender or education level ($X^2 \leq 6.68$, df = 3, $p \geq 0.08$) between the low, medium, high and all variant conditions.

Again, the individual item scores were combined to form scales for "overall perceived risk" (Cronbach's α = 0.93; M = 7.09; SD = 1.93), "mitigation behaviors" (Cronbach's α = 0.86; M = 6.24; SD = 2.02) and "preventative control" (Cronbach's α = 0.88; M = 4.80; SD = 2.50) (see Table IV in the Appendix for mean and median scores on each measure for each condition and for each graph literacy group). As anticipated, nearly all participants (93%) correctly answered at least four of the five questions designed to promote engagement with the content of the graph (Md = 5; M = 4.57; SD = 0.63). By contrast, the thirteen items in the GLS more effectively discriminated between the differences in the participant's ability to understand, utilize and make inferences from graphical data (Md = 11; M = 10.70; SD = 1.54). Hence, participants were split into two groups (lower or higher graph literacy) based on the median GLS score: 38.1% (n = 77) of participants with 10 items or less correct were classified as less graph literate, and 61.9% (n = 125) of participants with 11 items or more correct were classified

as more graph literate. As observed here, it is common to obtain a skewed distribution of scores on the GLS where the observed median score is higher than the scale's mid-score.[see 75]

An ANOVA showed that overall perceived risk for the low variant group (M = 7.03; SD = 2.10), medium variant group (M = 6.99; SD = 1.74), high variant group (M = 7.08; SD = 1.89) and all variants group (M = 7.11; SD = 2.02) did not differ significantly, $F(3, 198) = 0.04$, $p = 0.991$. Similarly, further ANOVAs showed that: willingness to adopt mitigation behaviors in the low variant group (M = 6.31; SD = 2.16), the medium variant group (M = 6.25; SD = 1.81), the high variant group (M = 6.04; SD = 2.17) and all variants group (M = 6.37; SD = 1.99) did not differ significantly, $F(3, 198) = 0.25$, $p = 0.864$; willingness to support preventative control in the low variant group (M = 5.13; SD = 2.48), the medium variant group (M = 4.47; SD = 2.61), the high variant group (M = 4.65; SD = 2.37) and all variants group (M = 4.96; SD = 2.58) did not differ significantly, $F(3, 198) = 0.72$, $p = 0.544$; there was also no significant difference, $F(3, 198) = 1.46$, $p = 0.228$, in graph consistency between the low variant (M = 5.46; SD = 2.58), medium variant (M = 5.77; SD = 2.29), high variant (M = 5.82; SD = 2.27) and all variants (M = 6.40; SD = 2.20) conditions. Hence, the *Graphical Displays Hypothesis* was rejected.

Three ANOVAs were then performed to determine whether overall perceived risk, willingness to employ mitigation behaviors and willingness to support preventative actions varied, respectively, depending upon the graph condition (low, medium, high) and the participant's level of graph literacy (less, more). The 'all condition' was excluded from this analysis on the basis that it could be confounded with the separate effects of each GPG variant on the measures of risk perception and behavior. The first ANOVA identified that perceived risk was significantly higher, $F(1, 146) = 11.04$, $p = 0.001$, in the more graph literate group (M = 7.45; SD = 1.58) than the less graph literate group (M = 6.45; SD = 2.16), but that there was no main effect for graph condition, $F(2, 146) = 0.19$, $p = 0.831$, and no interaction between

graph condition and graph literacy, $F(2, 146) = 0.35$, $p = 0.709$. The second ANOVA showed that willingness to employ mitigation behaviors was significantly higher, $F(1, 146) = 5.70$, $p = 0.018$, in the more graph literate group ($M = 6.52$; $SD = 1.76$) than the less graph literate group ($M = 5.75$; $SD = 2.32$), but that there was no main effect for graph condition, $F(2, 146) = 0.16$, $p = 0.853$, and no interaction between graph condition and graph literacy, $F(2, 146) = 2.51$, $p = 0.085$. Similarly, the third ANOVA found that willingness to support preventative actions was significantly higher, $F(1, 146) = 5.28$, $p = 0.023$, in the more graph literate group ($M = 5.14$; $SD = 2.41$) than the less graph literate group ($M = 4.19$; $SD = 2.50$), but that there was no main effect for graph condition, $F(2, 146) = 0.45$, $p = 0.638$, and no interaction between graph condition and graph literacy, $F(2, 146) = 0.41$, $p = 0.664$.[2]

2.3.4. Discussion

The findings from Study 3 showed that the graphs depicting various GPG projections had no discernable effect on the whole sample's perceived risk of GPG and no effect on their willingness to manage the associated risks via mitigation behaviors or the control of population numbers. This lack of an effect was even present when the graphs depicted high variant projections which showed that the global human population would reach over sixteen billion by 2100 (a further growth of nine billion people in under 90 years). The absence of an effect is particularly surprising because scientific evidence and theoretical arguments suggest that the probability of adverse events (e.g., global resource shortages, climate change, sudden mass migrations) will be positively correlated with the size of the global population. Moreover, even though perceived risk and the willingness to mitigate and prevent GPG were all higher among the more graph literate participants, there was no effect for graph type and no interaction between graph literacy and graph type. In other words, Study 3 shows that although higher levels of perceived risk and willingness to mitigate and prevent GPG were evident among

participants with more (cf. less) graph literacy, this relationship was highly generalized and did not vary according to the population numbers depicted in the graphs.

A potential explanation for this finding could be that many individuals, irrespective of their graph literacy skills, have little reaction to differences in the numerical information that is represented in such graphs because the graphs alone reveal nothing about the potential influence that large variations in human numbers could have on future living conditions. Galesic and Garcia-Retamero suggest that individuals high in graph literacy have a greater ability to "… *read beyond the data, or make inferences and predictions from the data.*"[58 p.445] However, the results of Study 3 suggest that, while such individuals may extract more meaning from the population graphs *per se*, they do not necessarily go as far as to make inferences about the potential different effects of large and rapid variations in future human numbers. This points towards the possibility that, irrespective of the variant depicted in the graphs, most individuals may develop a general 'global impression' of risk from the graphs and that this risk impression is greater amongst those who are typically better at extracting meaning from such formats.[55,76,77] Thus, the results of Study 3 indicate that whether a graph depicts low, median or high projected population numbers this does little to influence the perceived risk of GPG and the willingness to mitigate or prevent its potential adverse effects.

3. GENERAL DISCUSSION

There is a lack of empirical research that has examined what influences public perceptions of GPG and the willingness to manage its potential adverse effects by engaging in mitigation behaviors or by restricting the extent of population growth. The research reported here makes important contributions towards filling this epistemological gap. Specifically, the results show that narratives focusing on the potential adverse effects of GPG can increase perceived risk and the willingness to engage in mitigation behaviors, but may not affect the willingness to support preventative actions. However, narratives focusing solely on the

potential benefits of GPG do not appear to attenuate risk perceptions. Importantly, the results also indicate that although a risk-focused GPG narrative can significantly increase perceived risk, this is much more likely to be the case when the message recipient has extant perceptions of GPG that are congruent with the message.

Although neither photographic images nor graphs were found to have a generalized influence on perceive risk, graphs were associated with greater perceived risk and a greater willingness to engage in mitigation behaviors and supportive preventive controls among individuals with higher graph literacy. Thus, it is evident that the influence of GPG communications may differ based on the presentation format and content used and may be interpreted differently by individuals based on differences in cognitive abilities. Furthermore, Studies 1 and 2 found that narratives and images focused on the potential adverse effects of GPG were much more consistent with the participant's extant understanding and perceptions of GPG. This suggests that many people may already be more familiar with and/or in agreement with messages that focus on the professed adverse (cf. beneficial) effects of GPG; a finding which is in line with recent research showing that GPG is generally perceived as a moderate-to-high risk event.[15]

While the present studies provide novel insights into the potential psychological influence of communications about GPG it is also important, as with all research, to adopt a critical perspective and consider alternative explanations for the findings. For example, it is possible that the significant effect of the risk narrative in Study 1 was attributable to a 'demand effect' whereby participants felt that the narrative was intended to stimulate or instill an awareness of the potential effects of GPG and, thereafter, that the risk perception measures provided an opportunity for them to demonstrate this awareness.[78] Furthermore, in Study 2 the photos were deliberately presented in isolation from other stimuli (except form the generic statement about current and projected GPG numbers) to specifically test for their individual

effects. However, it is possible that presenting the photos in this manner meant that they carried little affective impact or appeared to have minimal direct relevance to the issue of GPG. Thus, it could be argued that Study 2 does not fully capture the potential impact that photos might have on GPG perceptions and behaviors when they are simultaneously presented with additional supporting materials. Similarly, it could also be asserted that the graphs presented in Study 3 would also have had a greater impact on perceptions and behaviors if they had been presented in conjunction with related information. However, what Study 3 does clearly show is that even when individuals do take on board specific information about vastly different projected GPG numbers, this information typically has little influence on risk perceptions. This finding is consistent with the results of Dawson and Johnson's study, which showed that knowledge of GPG numbers and GPG risk perceptions were not correlated.[15]

3.1. Recommendations for GPG Risk Communications

It is because risk- and benefit-related communications have a strong capacity to influence important risk management behaviors that those who create and deliver such messages are in a position of distinct ethical responsibility.[16,79] If, as many academic articles suggest, recent and future GPG can increase the likelihood of major global adverse events (e.g., climate change, resource shortages, accelerated species extinctions, ecosystem loss, rapid mass migrations, etc.) then GPG communications could play a central role in motivating the effort to manage these risks. Therefore, it would seem reasonable to assert that information about the projected extent and potential effects (whether positive or negative) of GPG should (i) aim to make such information easy to comprehend (ii) provide advice on feasible risk/benefit management actions and (iii) be based on an empirically informed understanding of how the information might be interpreted and used by the recipients. However, in light of the potential moderating effect of prior knowledge and perceptions on the interpretation of GPG narratives (Study 1), communications may benefit from the inclusion of content that explicitly

acknowledges both risks and benefits, and which presents valid and reliable evidence to support assertions that may be incongruent with the audience's extant views.

As demonstrated by the present studies, it cannot be assumed that certain communication formats and contents (e.g., photographic images of the adverse effects of human actions on the natural environment) will lead to specific effects (e.g., heightened risk perceptions and greater willingness to manage the potential risks). If future GPG has the potential to drive future catastrophic outcomes, then it seems reasonable to suggest that individuals, groups and organizations should be able to access a balanced range of information about managing the associated risks and realizing the potential benefits, and that this information is communicated via techniques that will have effects which are, as a result of empirical research, clearly understood. For example, as illustrated by Studies 2 and 3, different images and graphs may have limited impacts on public risk perceptions of GPG and, therefore, those who wish to inform people about the potential adverse effects of GPG might look to use narratives that provide details of the potential outcomes and their relationship to GPG. However, as highlighted by Study 1, it cannot be assumed that a risk-related narrative will necessarily increase support for action to further slow future GPG or, conversely, that a benefits-related narrative would attenuate risk perceptions.

3.2. Limitations and Future Research

It is important to recognize that there are some limitations to the present studies and that these shortcomings highlight potential directions for future research. First, the studies presented here have separately examined the effects of three communication formats with a view to understanding their individual effects on risk perceptions and behavioral intentions. Hence, the studies did not determine the extent to which these formats might become more/less influential when used in combination with one another. Second, the range of mediums and formats examined in the present studies is relatively small compared to the range that are used

in GPG communications in real-life contexts (e.g., population clocks, short videos, interactive maps, etc.). Therefore, future research might examine the effects of these different GPG communication approaches and/or aim to determine whether the findings from the present study are replicated in more naturalistic contexts. Third, it is not possible to be specific about the extent to which the results are generalizable beyond the samples observed and, therefore, caution should be exercised in concluding that the same results would be evident among other populations. Relatedly, Dawson & Johnson observed that age was positively correlated with the perceived risk of GPG, yet this relationship was not evident in either of the three studies presented here. This may have been because the samples in the present studies had a lower mean age (with a low standard deviation) than the sample in Dawson & Johnson's study.[15] This illustrates that the present studies lacked the capacity to determine whether older generations might be more/less influenced by different GPG communications. Finally, Study 3 was the only study in which specific differences in each participant's cognitive abilities (i.e., graph literacy) was formally assessed. However, it may have been that differences in individual abilities were relevant to the way in which the participants in Studies 1 and 2 processed the communication materials and, therefore, relevant abilities should be assessed in similar future studies. For example, examining the influence of individual differences, such as how science literacy affects interpretations of GPG narratives or how a greater need for affective cognitions influences the attention paid to GPG imagery, could provide further important insights into how these communications might influence risk perceptions and behaviors.[80,81]

4. CONCLUSION

Public perceptions of the potential adverse effects of GPG may be a key component in motivating important risk management behaviors during this century. Hence, there is clearly much value in developing a better understanding of what influences these perceptions and what effects they may have on the decisions and behaviors of all individuals, communities and

organizations. The studies presented here have contributed towards developing this understanding and have highlighted how GPG perceptions and related behavioral intentions can vary relative to differences in extant knowledge, cognitive ability, communication formats and contents. However, there still remains much scope for further research in this important field of study.

FOOTNOTES

1. To ensure that the analysis performed in Study 2 was consistent with that performed in Study 1, a test was conducted to determine if image consistency moderated the non-significant relationship between image type and perceived risk (the control group were excluded from the analysis because this group were not asked to provide image consistency data). The analysis did not identify a significant moderation effect (b = -0.055, 95%CI [-0.562, 0.451], t = -0.216, p = 0.451).

2. To ensure that the analysis was consistent with that performed in Study 1, a test was performed to determine if graph consistency moderated the non-significant relationship between graph condition and perceived risk. The analysis did not identify a significant moderation effect (b = 0.064, 95%CI [-0.117, 0.135], t = 0.144, p = 0.885).

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TABLES

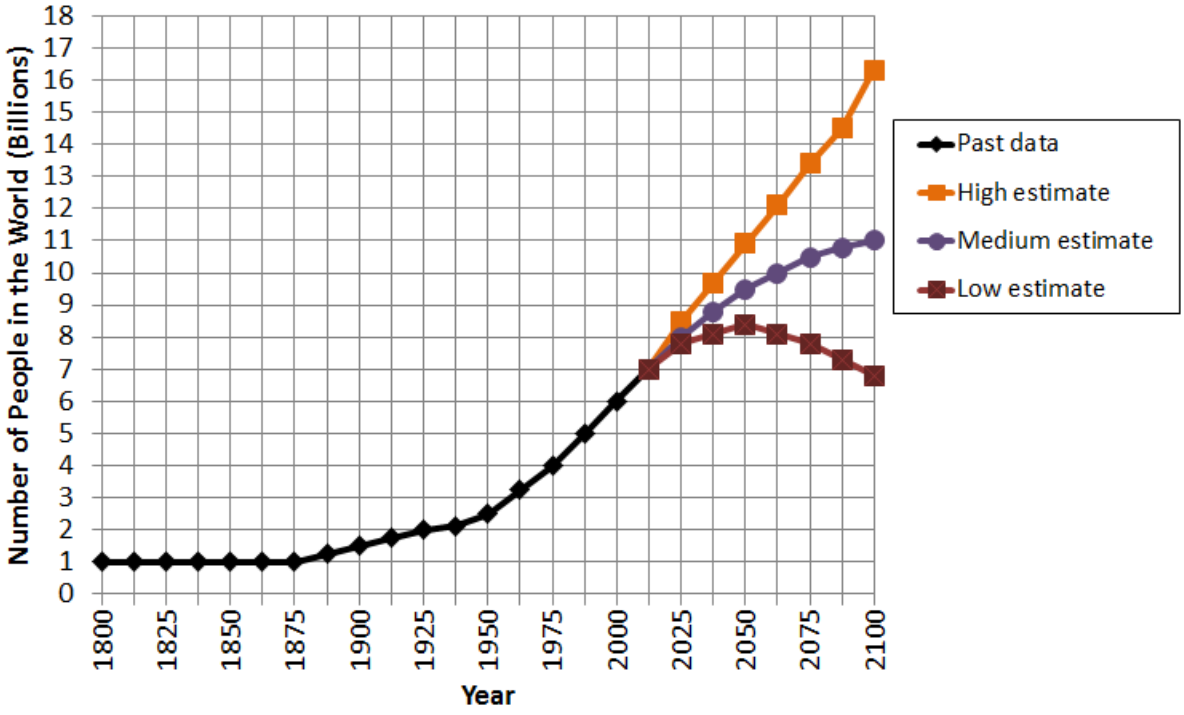
Table I. Titles and descriptions of each scene depicted in the positive images condition and negative images condition of Study 2.

Title provided with image	**Scene depicted in photograph**	
	Positive images group	*Negative images group*
People build homes to live in	A single detached dwelling in the woods on a sunny day	A massive urban development featuring thousands of dwellings and industrial buildings covered in hazy smog (no sky or green/natural space visible)
People share the available physical space	Two people walking in a large expanse of open rural land surrounded by mountains and trees	Thousands of people tightly crowded in a busy market place
People use the Earth's resources	A man hand-picking oranges from a tree on a sunny day	A giant excavated mine (over 1km in diameter) that dwarfs nearby industrial roads and buildings
People produce waste that needs to be managed	A man putting glass jars into a glass-recycling bin	A vast landfill site emitting a hazy smog (no green/natural space visible)
People use vehicles to get around	A person riding a bike through a quiet park filled with trees and flowers	An aerial view of thousands of new cars in a giant parking lot. The cars fill the image from left-to-right and top-to-bottom
People create and consume electricity and other energy sources	A low-energy lightbulb with green grass and trees in the background	A large industrial power station with six big chimneys emitting white fume clouds
People share the environment with animal species and plant species	A boy feeding a donkey water that appears to have been gathered from a nearby well	An aerial view of a landscape that has been subjected to large-scale deforestation
People use a variety of farming techniques to produce food	Two farmers manually digging and tending to a small number of crops	An aerial view of a world's largest greenhouse array that covers all visible land and extends into the clouds on the horizon

FIGURES

Figure 1. Example of one image shown in the negative images condition (left) and one image shown in the positive images condition (right) of Study 2. Both images had the title '*People use the Earth's resources*'.

Figure 2. Graph depicting global human population numbers from 1800 to 2100 (as used in the 'All' condition of Study 3). Numbers from 1800 to 2012 based on data published by the United States Census Bureau (2012). Numbers from 2013 to 2100 based on median population projections published by the United Nations Population Division (2013).



APPENDIX

Risk narrative presented in Study One

First, as the population of the world gets bigger, humanity is typically unprepared to respond to the changes that this causes, such as the increase in demand for food, housing, energy and public services. In turn, this substantially lowers living standards and even results in protests, migrations and violent conflicts. Second, as the population of the world increases there become more and more people who are exposed to natural disasters, famines and outbreaks of deadly diseases. Third, as the world population grows the amount of fossil fuels that people use as a source of energy also increases. This raises pollution levels and speeds up human-induced climate change. Fourth, as humanity builds more homes, workplaces, roads, etc. to respond to population growth, natural wildlife habitats are destroyed and this increases the rate at which certain animals becoming extinct. Finally, the human population is currently growing at the fastest rate in the world's poorest regions. People living in such areas will struggle to get out of poverty due to the pressures that they experience when trying to support their large families within a rapidly growing society. Overall, global population growth hinders and damages the prosperity of all humans.

Benefits narrative presented in Study One

First, history shows that as the population gets bigger, humans cope with this change by developing new technologies and creating more efficient and environmentally-friendly ways of doing things. In turn, this stimulates the economy, creates new jobs and raises living standards. Second, as the population of the world increases there are more people who can respond to crises and disasters and work to achieve common goals, such as tackling the outbreak of a deadly disease or helping earthquake victims. Third, when there are more people in the world they can all share the cost of funding public services such as schools, hospitals and environmental management, making these services cheaper to provide and more widely

available. Fourth, when parents have more children they work harder to provide for their children, this means that the parents make a greater contribution to the economy. Finally, the birth of children also helps the economy because the existence of the children creates a need for the production of more food, clothes, housing, schools, etc. and, importantly, the children eventually grow up to become part of a bigger future workforce. Overall, global population growth maintains and enhances the prosperity of all humans.

Table II. Study 1 (GPG narratives). Mean responses to questions concerning risk perceptions of GPG, and willingness to adopt mitigation and precautionary behaviors.

Scale label and response options	*Item*	*Narrative Condition*	*Mean (SD)*	*Median*
Overall perceived risk. 11-point scale (0 = strongly disagree, 10 = strongly agree)	Concerned about increased violent conflicts	Control	6.28 (2.37)	7.0
		Risks	7.04 (2.05)	7.0
		Benefits	6.26 (2.76)	6.0
	Concerned about increased disaster deaths	Control	5.46 (2.37)	6.0
		Risks	6.74 (2.35)	7.0
		Benefits	5.76 (2.51)	6.0
	Concerned about increased ecosystem damage	Control	6.84 (2.66)	7.0
		Risk	7.44 (2.00)	8.0
		Benefits	6.80 (2.79)	7.5
	Concerned about increased species extinction	Control	6.60 (2.42)	7.0
		Risks	7.22 (2.53)	8.0
		Benefits	7.00 (2.77)	8.0
	Concerned about increased energy shortages	Control	6.62 (2.52)	7.0
		Risks	7.16 (2.32)	7.5
		Benefits	6.36 (2.69)	7.0
	Concerned about increased food/water shortages	Control	6.86 (2.68)	7.5
		Risks	7.46 (2.38)	8.0
		Benefits	6.94 (2.65)	8.0
	Concerned about increased climate change	Control	6.32 (2.92)	7.0
		Risks	7.26 (2.29)	7.0
		Benefits	6.68 (2.98)	7.5
	Concerned about global economic decline	Control	5.08 (2.62)	5.0
		Risks	7.04 (2.20)	7.0
		Benefits	5.02 (2.48)	5.0

	Risk to humanity	Control	5.94 (2.70)	6.5
		Risks	6.76 (2.36)	7.0
		Benefits	6.02 (2.81)	6.5
Mitigation behaviors. 11-point scale (0 = strongly disagree, 10 = strongly agree)	Reduce consumption of food and water	Control	4.32 (2.88)	5.0
		Risks	5.76 (2.88)	6.0
		Benefits	4.55 (2.94)	5.0
	Reduce amount of travel via fossil fuel-powered vehicles	Control	5.48 (2.98)	6.0
		Risks	7.12 (2.34)	7.0
		Benefits	5.98 (2.78)	6.0
	Reduce quantity of material goods purchased	Control	5.66 (2.96)	6.0
		Risks	6.98 (2.35)	7.0
		Benefits	5.57 (2.89)	6.0
	Reduce consumption of products and services that are unfriendly to the environment	Control	6.62 (2.59)	7.0
		Risks	7.48 (2.04)	8.0
		Benefits	6.31 (2.84)	7.0
Preventative control. 11-point scale (0 = strongly disagree, 10 = strongly agree)	Donate money to charity that works to reduce global population growth	Control	3.54 (3.09)	3.5
		Risks	4.54 (3.22)	5.0
		Benefits	3.86 (2.85)	4.0
	Pay more taxes to reduce global population growth	Control	3.42 (3.16)	3.5
		Risks	4.24 (3.07)	4.0
		Benefits	3.67 (2.78)	3.0
	Vote for political party that would spend more public money on reducing global population growth	Control	4.62 (3.19)	5.0
		Risks	5.32 (2.97)	5.5
		Benefits	4.63 (3.03)	5.0

Table III. Study 2 (GPG images). Mean responses to questions concerning risk perceptions of GPG, and willingness to adopt mitigation and precautionary behaviors.

Scale label and response options	*Item*	*Images Condition*	*Mean (SD)*	*Median*
Overall perceived risk. 11-point scale (0 = strongly disagree, 10 = strongly agree)	Concerned about increased violent conflicts	Control	6.42 (2.59)	7.0
		Negative	6.05 (2.88)	6.0
		Positive	6.41 (2.82)	7.0
	Concerned about increased disaster deaths	Control	5.97 (2.72)	6.0
		Negative	5.90 (2.63)	6.0
		Positive	5.59 (2.64)	6.0
	Concerned about increased ecosystem damage	Control	7.59 (2.34)	8.0
		Negative	6.95 (2.99)	8.0
		Positive	6.81 (2.81)	7.0
	Concerned about increased species extinction	Control	7.32 (2.44)	8.0
		Negative	7.17 (2.96)	8.0
		Positive	6.83 (2.87)	7.0
	Concerned about increased energy shortages	Control	7.12 (2.51)	8.0
		Negative	6.46 (2.79)	7.0
		Positive	6.66 (2.67)	7.0
	Concerned about increased food/water shortages	Control	7.90 (2.20)	8.0
		Negative	7.14 (2.84)	8.0
		Positive	7.20 (2.63)	8.0
	Concerned about increased climate change	Control	7.53 (2.49)	8.0
		Negative	6.75 (3.19)	8.0
		Positive	6.75 (2.87)	8.0
	Concerned about global economic decline	Control	5.73 (2.53)	7.0
		Negative	5.03 (2.90)	5.0
		Positive	5.90 (2.62)	6.0

	Risk to humanity	Control	7.00 (2.62)	8.0
		Negative	6.47 (3.11)	7.0
		Positive	6.78 (2.69)	8.0
Mitigation behaviors. 11-point scale (0 = strongly disagree, 10 = strongly agree)	Reduce consumption of food and water	Control	5.71 (2.95)	6.0
		Negative	5.60 (2.82)	6.0
		Positive	5.17 (3.03)	5.0
	Reduce amount of travel via fossil fuel-powered vehicles	Control	6.47 (2.73)	7.0
		Negative	6.12 (3.00)	7.0
		Positive	5.73 (3.19)	6.0
	Reduce quantity of material goods purchased	Control	6.36 (2.74)	7.0
		Negative	6.24 (2.67)	7.0
		Positive	5.80 (3.23)	7.0
	Reduce consumption of products and services that are unfriendly to the environment	Control	7.14 (2.20)	7.0
		Negative	6.91 (2.66)	8.0
		Positive	6.37 (2.99)	7.0
Preventative control. 11-point scale (0 = strongly disagree, 10 = strongly agree)	Donate money to charity that works to reduce global population growth	Control	4.64 (2.78)	5.0
		Negative	4.47 (2.96)	5.0
		Positive	4.10 (3.11)	5.0
	Pay more taxes to reduce global population growth	Control	4.68 (3.09)	5.0
		Negative	3.93 (3.09)	4.0
		Positive	4.14 (3.02)	4.0
	Vote for political party that would spend more public money on reducing global population growth	Control	5.93 (2.95)	6.0
		Negative	5.14 (3.36)	5.0
		Positive	5.32 (3.32)	6.0

Table IV. Study 3 (GPG graphs). Mean responses to questions concerning risk perceptions of GPG, and willingness to adopt mitigation and precautionary behaviors.

Scale label and response options	*Item*	*Graph Condition*	*Mean (SD)*	*Median*	*Lower Graph Literacy Mean (SD)*	*Higher Graph Literacy Mean (SD)*
Overall perceived risk. 11-point scale (0 = strongly disagree, 10 = strongly agree)	Concerned about increased violent conflicts	Low	6.50 (2.51)	6.0	6.47 (3.00)	6.52 (2.27)
		Medium	7.04 (2.14)	7.0	6.90 (2.23)	7.13 (2.11)
		High	6.80 (2.33)	7.0	6.24 (2.47)	7.36 (2.08)
		All	7.20 (2.23)	7.0	7.69 (2.21)	7.03 (2.24)
	Concerned about increased disaster deaths	Low	6.38 (2.63)	7.0	6.00 (3.06)	6.58 (2.41)
		Medium	5.94 (2.34)	6.0	5.67 (2.13)	6.13 (2.49)
		High	6.28 (2.58)	7.0	6.00 (2.66)	6.56 (2.52)
		All	5.98 (2.38)	6.0	6.46 (2.79)	5.81 (2.23)
	Concerned about increased ecosystem damage	Low	7.54 (2.21)	8.0	6.47 (3.09)	8.09 (1.33)
		Medium	7.27 (2.26)	7.0	6.38 (1.96)	7.87 (2.28)
		High	7.56 (2.38)	8.0	6.68 (2.75)	8.44 (1.53)
		All	7.84 (2.01)	8.0	8.38 (1.98)	7.64 (2.02)
	Concerned about increased species extinction	Low	7.40 (2.70)	8.0	6.47 (3.32)	7.88 (2.23)
		Medium	7.27 (2.03)	8.0	6.43 (2.04)	7.84 (1.85)
		High	7.30 (2.42)	8.0	6.52 (2.49)	8.08 (2.12)
		All	7.53 (2.03)	8.0	7.92 (2.25)	7.39 (1.96)
	Concerned about increased energy shortages	Low	7.32 (2.39)	8.0	6.35 (3.00)	7.82 (1.86)
		Medium	7.42 (2.04)	7.0	6.90 (1.90)	7.77 (2.09)
		High	7.24 (2.39)	8.0	6.56 (2.69)	7.92 (1.85)
		All	7.59 (3.58)	8.0	7.36 (2.62)	7.47 (1.99)
	Concerned about increased food/water shortages	Low	7.50 (2.32)	8.0	6.59 (3.02)	7.97 (1.74)
		Medium	7.75 (2.12)	8.0	7.43 (1.94)	7.97 (2.24)
		High	7.70 (2.10)	8.0	7.08 (2.29)	8.32 (1.73)
		All	7.84 (2.07)	8.0	7.57 (2.98)	7.72 (2.07)

	Concerned about increased climate change	Low	7.50 (2.52)	8.0	6.65 (3.16)	7.94 (1.48)
		Medium	7.23 (2.92)	8.0	7.05 (2.31)	7.35 (3.30)
		High	7.60 (2.74)	8.5	6.92 (2.97)	8.28 (2.35)
		All	7.47 (2.27)	8.0	8.31 (1.89)	7.17 (2.35)
	Concerned about global economic decline	Low	6.10 (2.54)	6.0	5.41 (3.10)	6.45 (2.17)
		Medium	6.02 (2.21)	6.0	5.90 (2.14)	6.10 (2.29)
		High	6.16 (2.24)	6.0	5.48 (2.60)	6.84 (1.57)
		All	6.57 (2.22)	7.0	6.46 (2.11)	6.61 (2.28)
	Risk to humanity	Low	6.68 (2.49)	7.0	6.06 (3.13)	7.27 (2.02)
		Medium	6.56 (2.63)	7.0	5.76 (2.32)	7.10 (2.73)
		High	6.94 (2.63)	7.0	5.76 (2.28)	8.12 (1.81)
		All	7.04 (2.44)	8.0	7.00 (3.16)	6.86 (2.42)
Mitigation behaviors. 11-point scale (0 = strongly disagree, 10 = strongly agree)	Reduce consumption of food and water	Low	5.20 (2.70)	6.0	4.00 (2.72)	5.82 (2.51)
		Medium	5.38 (2.19)	6.0	5.24 (2.30)	5.48 (2.14)
		High	5.14 (2.52)	5.0	5.08 (2.52)	5.20 (2.57)
		All	5.60 (2.68)	6.0	5.71 (2.49)	5.56 (2.78)
	Reduce amount of travel via fossil fuel-powered vehicles	Low	6.64 (2.55)	7.0	5.41 (3.06)	7.27 (2.02)
		Medium	6.33 (2.41)	6.0	6.62 (1.88)	6.13 (2.72)
		High	6.44 (2.64)	7.0	6.48 (2.68)	6.40 (2.65)
		All	6.42 (2.38)	7.0	6.79 (2.33)	6.28 (2.42)
	Reduce quantity of material goods purchased	Low	6.18 (2.55)	6.0	5.06 (2.88)	6.76 (2.18)
		Medium	6.33 (2.28)	7.0	6.19 (2.58)	6.42 (2.09)
		High	5.88 (2.47)	6.0	5.96 (2.48)	5.80 (2.52)
		All	6.20 (2.33)	7.0	6.86 (2.21)	5.94 (2.35)
	Reduce consumption of products and services that are unfriendly to the environment	Low	7.20 (2.31)	7.0	5.82 (2.79)	7.91 (1.67)
		Medium	6.96 (2.26)	7.0	6.19 (2.34)	7.48 (2.08)
		High	6.70 (2.47)	7.0	6.24 (2.82)	7.16 (2.01)
		All	7.26 (2.20)	7.5	7.79 (2.36)	7.06 (2.14)
Preventative control. 11-point scale (0 = strongly disagree,	Donate money to charity that works to reduce global population growth	Low	5.06 (2.63)	5.0	4.06 (2.86)	5.58 (2.39)
		Medium	4.25 (2.81)	5.0	3.90 (2.72)	4.48 (2.90)
		High	4.34 (2.62)	4.0	3.92 (2.55)	4.76 (2.67)
		All	4.30 (2.87)	5.0	4.00 (2.48)	4.42 (3.03)

10 = strongly agree)	Pay more taxes to reduce global population growth	Low	4.54 (2.94)	5.0	3.47 (3.11)	5.09 (2.73)
		Medium	4.27 (2.93)	5.0	4.19 (2.99)	4.32 (2.93)
		High	4.42 (2.73)	5.0	4.08 (2.78)	4.76 (2.68)
		All	4.60 (2.98)	5.0	4.86 (2.48)	4.50 (3.19)
	Vote for political party that would spend more public money on reducing global population growth	Low	5.78 (2.95)	6.0	5.06 (3.33)	6.15 (2.72)
		Medium	4.88 (2.80)	5.5	4.43 (3.06)	5.19 (2.61)
		High	5.18 (2.52)	5.0	4.56 (2.47)	5.80 (2.47)
		All	5.98 (2.68)	6.0	5.86 (2.51)	6.03 (2.78)