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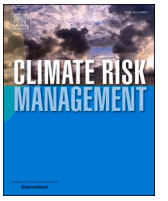

Effects of information exposure on risk perception and worry about ocean acidification: Evidence from Norway and the UK

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ABSTRACT

This paper reports on an investigation in which risk perception and worry were assessed before and after information about possible consequences of ocean acidification was presented in the form of short-written messages. Study 1 ($N = 289$, Norway sample) found no support for a causal effect of a message incorporating simple factual information, yet a vivid information message was associated with increased risk perception and worry. Both messages increased the ability to mentally imagine the cause and effects of ocean acidification, but the magnitude of these effects did not account for the comparatively stronger effects of vivid information. Study 2 ($N = 298$, UK sample) partially replicated these effects in a different national context. While the vivid message increased risk perception and worry about ocean acidification, effects from the simple factual message were less consistent. Being presented plain facts showed an effect on worry and perceived severity, but the perceived likelihood of threat from ocean acidification remained similar to a control condition. Exposure to plain or vivid information about current and future impacts of ocean acidification each increased mental imagery, but these effects were again comparable between the two message conditions. These findings are discussed in the context of communication strategies that target public awareness about climate-related risks.

1. Introduction

From the start of the industrial revolution until the mid-2000s, the ocean has absorbed around 31% of global anthropogenic carbon dioxide (CO_2) emissions (Gruber et al., 2019; Sabine et al., 2004). The carbon-sinking role of the ocean helps moderate climate change, but this process also substantially changes the ocean's chemistry and gives rise to ocean acidification – a phenomenon commonly referred to as the 'evil twin' of climate change (Cooke and Kim, 2019). Over the last 200 years, the pH of the world's oceans has declined by 0.1 units due to ocean acidification (Raven et al., 2005). This rising acidity threatens the growth and survival of many marine species, particularly calcifying species (Kroeker et al., 2010). It also has negative economic impacts on millions of people around the world whose livelihoods depend on marine fisheries and aquaculture (Hall-Spencer and Harvey, 2019).

Despite its significance for life in marine environments, and their associated industries, public awareness of ocean acidification tends to be rather low. In a UK study conducted between 2013 and 2014, over 80% of respondents had never heard of ocean acidification prior to participating in the study (Capstick et al., 2016). Another UK national study conducted in 2016 reported that about

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70% of respondents had no prior awareness of ocean acidification (Spence et al., 2018). Low awareness of ocean acidification has also been reported among samples from the US (Cooke and Kim, 2019), from New Zealand (Eddy, 2014; Kolandai-Matchett et al., 2021), and in several European countries (Buckley et al., 2017). The exception to this trend is a study of US shellfish industry workers where most respondents showed high levels of concern and self-rated knowledge regarding ocean acidification (Mabardy et al., 2015), along with studies showing that ocean acidification emerged as an issue of concern among stakeholders in the coastal regions of Norway (Dannevig et al., 2019; Koenigstein et al., 2016).

Much of the motivational influence of awareness comes from recognising the threat(s) environmental problems pose to objects of value.[2] These objects of value may include the well-being of oneself or other humans, as well as concerns for non-human life forms or physical aspects of the environment. This conceptualisation of awareness overlaps with the concept of risk perception, which refers to subjective judgments of events or situations that could have negative consequences for value objects (Breakwell, 2007). Risk perception specifically involves cognitive judgements about the likelihood and severity of negative consequences (Slovic, 1999). Anticipatory emotions (worry) evoked by perceived threats to value objects also operate alongside these judgements as antecedents of actions and decision-making. Although risk perception regarding climate change tends to be positively correlated with worry (Sundblad et al., 2007), the two factors do not always converge (Sjoberg, 1998). In circumstances where worry and risk perception are not aligned, worry is likely to be the more dominant influence on behaviour (Loewenstein et al., 2001).

Risk perception and worry are elements of awareness that can act as motivations for individual action and policy support regarding amelioration of environmental risks (O'Connor et al., 1999; Smith and Leiserowitz, 2014; Wang et al., 2018). Consequently, it is important to identify strategies for communicating with the public about ocean acidification in ways that may heighten risk perception and engage people emotionally. In two previous studies, exposure to short expository messages was shown to result in a significant increase in concern about ocean acidification in the UK (Capstick et al., 2016) and the US (Cooke and Kim, 2019). Concern was measured before and after people were exposed to basic facts about ocean acidification, and the focus of the analyses was on social-psychological factors that predicted any observed changes in concern. However, because these studies did not include a 'control' group of people who received no information, their findings do not establish a causal effect of information exposure on concern about ocean acidification. The primary aim of the current investigation was to address this gap in the literature.

Besides determining the overall causal effects of giving people information about ocean acidification, another important aim was to investigate whether the magnitude of these effects vary according to the type of narrative style used when providing the information. Specifically, we contrasted the plain or cautious style favoured by scientists when presenting facts about climate risks (Brysse et al., 2013) with the more graphic or vivid language commonly used in media reports (Boykoff and Pearman, 2019). In the following, we report on two studies in which the participants were randomly assigned to one of three experimental conditions – a *factual message* condition, a *vivid message* condition, or a *control* condition. In addition to testing whether any potential effects on perceived risk and worry hold robust across national contexts, we were also interested in comparing the ability from different messages in shaping a person's mental image about ocean acidification.[3]

2. Study 1

2.1. Sample

Participants ($N = 289$, $M_{age} = 27.3$, $SD_{age} = 7.03$, $n_{female} = 202$, $n_{male} = 82$, $n_{missing} = 5$) were recruited from the research participant pool of the Digital Social Science Core Facility (DIGSSCORE; https://www.uib.no/en/digsscore) at the University of Bergen (Norway) in early 2021. Entry into a lottery to win one out of three available digital shopping vouchers worth NOK 2000[4] was offered as an incentive for participation. We used G*Power 3.1 (Faul et al., 2009) to determine the minimum sample size ($N = 251$) required to detect a medium effect (Cohen's $f = 0.25$, $\alpha = 0.05$, $1 - \beta = 0.95$) from experimental condition on the outcome measures. This was informed by the lower end of the effect size estimates that were reported in prior studies (Capstick et al., 2016; Cooke and Kim, 2019). In addition, we oversampled by approximately +10% of the minimum sample size to accommodate potential missing data.

2.2. Design

This study employs a 2 (time: before message, after message) × 3 (condition: factual message, vivid message, control) design to compare effects across different experimental conditions. All outcome measures were assessed both before (T1) and after (T2) exposure to the contents of each condition. An overview of these measures (worry, perceived severity, perceived likelihood, and mental imagery) and further covariates that were included in the analyses (biospheric values, prior knowledge, attentional focus, age, gender, and political orientation) can be found below.

[2] Awareness can empower people to respond to environmental risks through knowledge of the causes and consequences of environmental problems, but also via knowledge about mitigation strategies (Jensen, 2002).

[3] See Zaleskiewicz et al. (2023) for further discussion on the role of mental imagery in decision-making.

[4] Equivalent to approximately USD230 in September 2021 (Source: https://www.oanda.com).

2.3. Procedures

Following up on a first (baseline) assessment of the outcome measures, the two message conditions were introduced as follows: "On the next page, you will be presented with some information about ocean acidification. Please read this information carefully before you proceed the questionnaire by clicking "next" at the bottom of the page". Participants in the factual message condition were presented with a plain scientific description of ocean acidification adopted from Capstick et al. (2016). Those in the vivid message condition received an excerpt from *The Uninhabitable Earth*, an essay by David Wallace-Wells published in New York Magazine in 2017. The excerpt was drawn from a section of the essay titled "poisoned oceans" (Wallace-Wells, 2017), which describes ongoing and potential effects of ocean acidification in lurid detail whilst being comparable in factual content to the plain scientific description. To adapt the vivid message condition for use in this study, we omitted the first paragraph of the original section and substituted a word ('holocaust') that might have been considered sensitive by some audiences.

Participants in the control condition did not receive any further information on ocean acidification but were instead given a task adapted from Stathi and Crisp (2008). The exact instructions to complete this task were as follows: "We would like you to spend the next two minutes imagining an outdoor scene. Try to imagine aspects of the scene around you (e.g., is it a beach, a forest, are there trees, hills, what's on the horizon?). In the space below, please list the different things you saw in the scene you just imagined".

After reading the assigned text in the two message conditions, or completing the task in the control condition, participants were directed to complete the rest of the questionnaire. The experimental materials and items were developed in English language and then translated to Norwegian by a competent bilingual speaker using a system of translation and back-translation (Brislin, 1970). The median time for completing the survey was 9.05 min, and there were no significant differences in completion time across conditions ($F_{(2,286)} = 0.55$, $p = .577$).

2.4. Measures

Prior engagement with environmental issues was measured with a four-item biospheric values scale (De Groot and Steg, 2008), asking participants to indicate how they rate harmony with other species, preserving nature, fitting into nature, and preventing pollution as guiding principles for their lives. Responses were measured on a nine-point scale from (−1) = 'Opposed to my values' and (0) = 'Not important' to (7) = 'Extremely important' ($\alpha = 0.82$).

We measured prior knowledge of ocean acidification with an item adopted from Capstick et al. (2016): "How much, if anything, would you say you know about ocean acidification?". Responses were recorded on a five-point scale ranging from (1) = 'I have not heard of ocean acidification before' to (5) = 'I know a great deal about ocean acidification'. Table 1 shows that around 45% of the sample indicated that they had either not heard of ocean acidification before or knew almost nothing about it, whereas only 1% indicated that they know a great deal about ocean acidification.

Worry was measured with a single item: "How worried, if at all, are you about ocean acidification right now?". Responses were recorded on a scale ranging from (1) = 'Not at all worried' to (5) = 'Extremely worried'.

Risk perception was measured with two items: "How severe a problem, if at all, would you say ocean acidification is?" and "How likely, if at all, do you think it is that ocean acidification could pose a serious threat during your lifetime?". These items were meant to capture the *perceived severity* and *perceived likelihood* dimensions of ocean acidification risk perception, respectively. Responses were assessed on five-point scales from (1) = 'Not at all severe/Not at all likely' to (5) = 'Extremely severe/Extremely likely'.

Mental imagery was measured with three items: "How easy is it for you to mentally visualise (imagine) the cause and effects of ocean acidification?", "Using the following scale, please indicate how vague or concrete your mental image of ocean acidification is?", and "How realistic (i.e., comparable to things you see in your day-to-day life) is your mental image of ocean acidification?". Responses were recorded with five-point scales from (1) = 'Very difficult/Very vague/Not very realistic' to (5) = 'Very easy/Very concrete/Very realistic' ($\alpha_{T1} = 0.85$; $\alpha_{T2} = 0.88$).

Three items asked about the extent to which the participants agree with the following statements: "I found my mind wandering while I completed the task", "While I completed the task, I found myself thinking about other things", and "I had a hard time keeping my mind on the task". These items were adapted from Busselle and Bilandzic (2009) to account for individual differences in attentional focus when the participants were exposed to the different conditions. Responses were assessed on a five-point scale from (1) = 'Strongly disagree' to (5) = 'Strongly agree' ($\alpha = 0.84$).

Table 1
Prior knowledge about ocean acidification in Study 1 (Norway sample) and Study 2 (UK sample).

	Study 1		Study 2	
	n	%	*n*	%
I have not heard of ocean acidification before	29	10.0	107	35.9
I have heard of ocean acidification, but I know almost nothing about it	101	34.9	107	35.9
I know just a little about ocean acidification	131	45.3	65	21.8
I know a fair amount about ocean acidification	25	8.7	17	5.7
I know a great deal about ocean acidification	3	1.0	2	0.7

Note. Respondents were asked the following question: "How much, if anything, would you say you know about ocean acidification?". Item adopted from Capstick et al. (2016).

Alongside age and gender, we also measured left–right political orientation for which an item was adopted from the literature (Ogunbode et al., 2020a, 2020b). Here, respondents positioned themselves on a 11-point scale anchored at (0) = 'Left' and (10) = 'Right': "In politics, people often talk about the 'left wing' and the 'right wing'. Below is a scale where 0 represents those who are on the far left politically, while 10 represents those who are on the far right. Where would you place yourself on such a scale?"

2.5. Analyses

Data was analysed using analyses of covariance (ANCOVA) in which pre-test measures for the outcome measures were included as a baseline measure, as recommended in the literature (Dugard and Todman, 1995; Oakes and Feldman, 2001). Each analysis was followed up by a series of post hoc tests using Bonferroni correction for adjusted p values. All models controlled for biospheric values, prior knowledge, attentional focus, age, gender, political orientation, in addition to the pre-test measures.

2.6. Results

We observed a significant main effect of information exposure on worry about ocean acidification ($F_{(2,274)} = 21.04$, $p < .001$, $\eta^2_{\text{partial}} = 0.13$; cf. Fig. 1). Post hoc tests showed that exposure to the vivid message ($M = 3.45$, $SE = 0.07$) produced significantly greater levels of worry about ocean acidification than the simple factual message ($M = 2.97$, $SE = 0.07$, $p < .001$, $d = 0.70$) and the control condition ($M = 2.82$, $SE = 0.07$, $p < .001$, $d = 0.92$). However, there was no significant difference in levels of worry between the simple factual message and the control condition ($p = .423$, $d = 0.22$).

Similarly, information exposure had a significant main effect on perceived severity of ocean acidification ($F_{(2,274)} = 25.63$, $p < .001$, $\eta^2_{\text{partial}} = 0.16$; cf. Fig. 1). Exposure to the vivid message ($M = 4.04$, $SE = 0.07$) produced significantly greater perceived severity of ocean acidification than the simple factual message ($M = 3.45$, $SE = 0.07$, $p < .001$, $d = 0.95$) and the control condition ($M = 3.49$, $SE = 0.07$, $p < .001$, $d = 0.89$), but there was no significant difference in how severe the risk of ocean acidification was perceived by the participants in the factual message and the control condition ($p = 1.000$, $d = 0.06$).

There was a significant main effect of information exposure on perceived likelihood of ocean acidification posing a threat ($F_{(2,274)} = 25.18$, $p < .001$, $\eta^2_{\text{partial}} = 0.16$; cf. Fig. 1). Here, we found a greater level of perceived likelihood threat among the participants exposed to the vivid message ($M = 3.49$, $SE = 0.07$) compared with those that received the simple factual message ($M = 2.92$, $SE = 0.07$, $p < .001$, $d = 0.93$) and the control condition ($M = 2.95$, $SE = 0.07$, $p < .001$, $d = 0.88$). The perceived likelihood of threat from ocean acidification did not differ significantly between the factual message and the control condition ($p = 1.000$, $d = 0.05$).

Finally, information exposure showed a significant main effect on mental imagery of ocean acidification ($F_{(2,274)} = 49.94$, $p < .001$, $\eta^2_{\text{partial}} = 0.27$; cf. Fig. 1), whereby participants exposed to the vivid message ($M = 3.57$, $SE = 0.06$, $p < .001$, $d = 1.35$) and those who received the factual message ($M = 3.46$, $SE = 0.06$, $p < .001$, $d = 1.16$) reported greater levels of mental imagery with respect to ocean acidification than those in the control condition ($M = 2.78$, $SE = 0.06$). However, there was no significant difference in mental imagery based on whether the participants read the vivid message or the factual message ($p = .624$, $d = 0.19$).

3. Study 2

3.1. Sample

A random sample of UK residents ($N = 298$, $M_{\text{age}} = 27.9$, $SD_{\text{age}} = 9.95$, $n_{\text{female}} = 214$, $n_{\text{male}} = 79$, $n_{\text{missing}} = 5$) were recruited from a commercial online survey panel in summer 2021. Each participant received a payment of £1.88 for completing the study. Using G*Power 3.1 (Faul et al., 2009), we estimated that a minimum sample size of $N = 164$ was needed to replicate the smallest main effect size detected in Study 1 (Cohen's $f = 0.31$, $\alpha = 0.05$, $1 - \beta = 0.95$). We oversampled to allow adequate power in the case of missing data.

3.2. Design

This study uses a 2 (time: before message, after message) × 3 (condition: factual message, vivid message, control) design to replicate effects of Study 1. Participants again responded to items measuring worry, perceived severity, perceived likelihood, and mental imagery once before (T1) and once again after (T2) they were exposed to the contents of each condition. For more information on these measures, and other covariates, see the section below.

3.3. Procedures

The procedures in which the participants were presented the content in each condition remained as described before. The median time for survey completion was 7.08 min, which was again comparable between the three experimental conditions ($F_{(2,295)} = 1.50$, $p = .224$).

3.4. Measures

At the start, we presented the participants with a similar selection of biospheric values items to measure their prior engagement

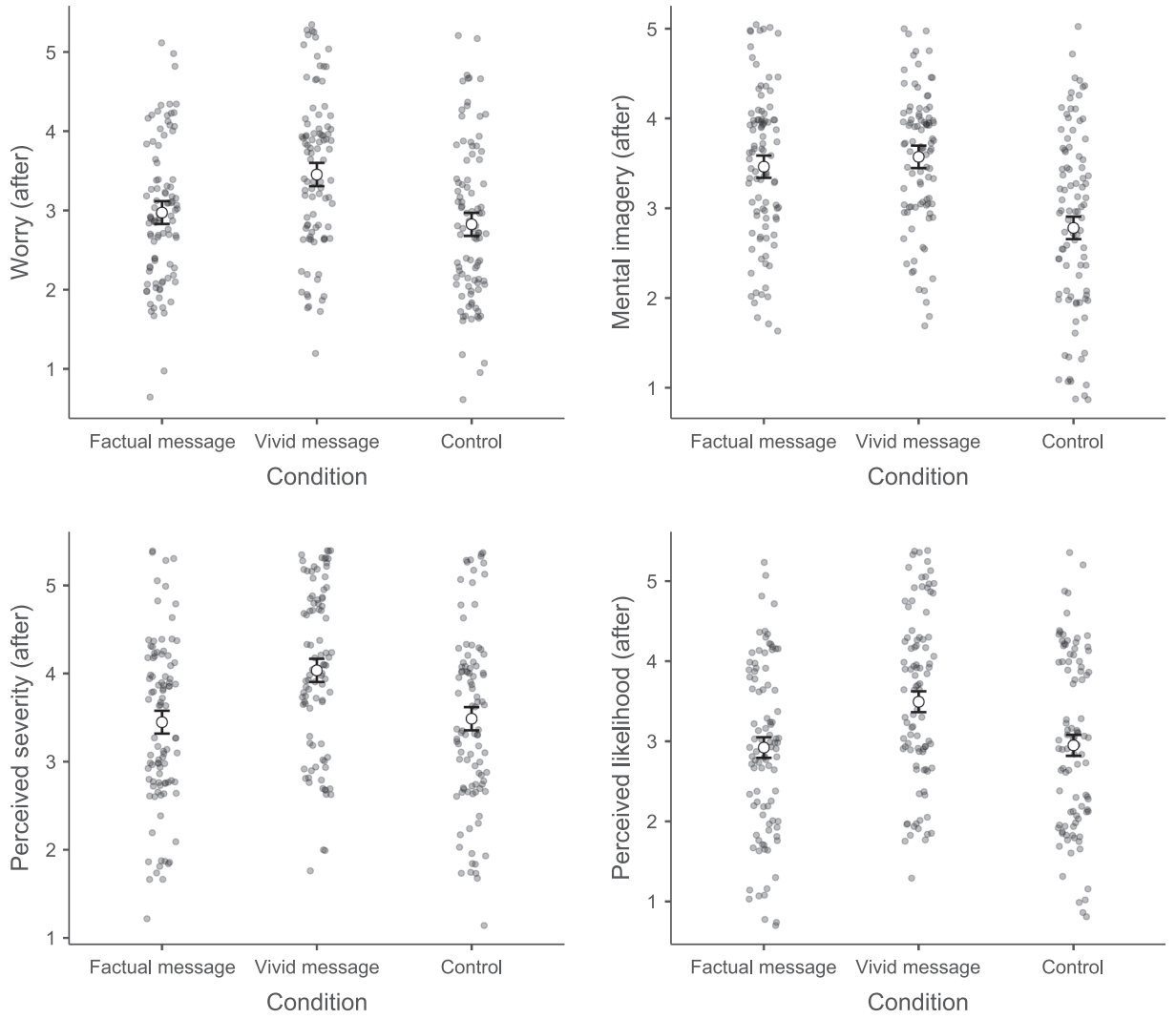

Fig. 1. Estimated marginal means plots for the outcome measures in Study 1 (Norway sample). Shown are observed scores and 95% confidence intervals after exposure to the contents in each condition.

with environmental issues. Responses were recorded based on a seven-point scale from (−1) = 'Opposed' and (0) = 'Not important' to (5) = 'Extremely important' ($\alpha = 0.89$). Prior knowledge was again measured with a single item, with more than 70% of the participants stating to have either not heard of ocean acidification before or to know almost nothing about it (see Table 1).

While the items that were used to measure *worry*, *perceived severity,* and *perceived likelihood* resembled those in Study 1, *mental imagery* was assessed based on the following: "How easy is it for you to mentally visualise (imagine) the cause of ocean acidification?", "How easy is it for you to mentally visualise (imagine) the effects of ocean acidification?", "Using the following scale, please indicate how vague or concrete your mental image of ocean acidification is", and "How realistic (i.e., comparable to things you see and experience in your day-to-day life) is your mental image of ocean acidification?".[5] Responses were given through five-point scales from (1) = 'Extremely difficult/Extremely difficult/Very vague/Not at all realistic' to (5) = 'Extremely easy/Extremely easy/Very concrete/Extremely realistic' ($\alpha_{T1} = 0.84$; $\alpha_{T2} = 0.88$).

In addition to responding to measures on age, gender, and political orientation, the participants were asked to answer three items that allowed us to assess their attentional focus ($\alpha = 0.90$) when they read the content of each condition. These items were formulated in the same way as in Study 1.

[5] Study 1 included one item that asked how easy it is to mentally visualise (imagine) the cause and effects of ocean acidification. This item may be seen as a double-barrelled question because it required the participants to provide a single answer with respect to two distinct dimensions of ocean acidification. Study 2 split this item into two questions to acknowledge that someone may find it easier to visualize the causes of ocean acidification than the consequences – and vice versa.

3.5. Analyses

We ran a series of ANCOVA, followed up by additional post hoc tests with Bonferroni correction, in line with the procedures from Study 1. Each of these analyses controlled for biospheric values, prior knowledge, attentional focus, age, gender, political orientation, and pre-test measures for either worry, perceived severity, perceived likelihood, or mental imagery.

3.6. Results

Information exposure showed a significant main effect on worry about ocean acidification ($F_{(2,278)} = 13.39$, $p < .001$, $\eta^2_{\text{partial}} = 0.09$; cf. Fig. 2). Post hoc tests revealed that self-reported worry was significantly greater among participants in the vivid message condition ($M = 3.47$, $SE = 0.07$) compared to those assigned to the factual message condition ($M = 3.14$, $SE = 0.07$, $p = .004$, $d = 0.48$) or the control condition ($M = 2.94$, $SE = 0.08$, $p < .001$, $d = 0.77$). Worry about ocean acidification was not significantly different for participants who received the factual message versus those who completed the control task ($p = .164$, $d = 0.29$).

A significant main effect of information exposure on perceived severity of ocean acidification was also replicated ($F_{(2,278)} = 29.90$, $p < .001$, $\eta^2_{\text{partial}} = 0.18$). Participants in the vivid message condition ($M = 4.06$, $SE = 0.08$, $p < .001$, $d = 1.15$) and in the factual message condition ($M = 3.56$, $SE = 0.07$, $p = .011$, $d = 0.44$) reported significantly greater perceived severity than those in the control condition ($M = 3.25$, $SE = 0.08$). Levels of perceived severity were on average significantly greater in the vivid message condition than in the factual message condition ($p < .001$, $d = 0.71$).

Information exposure also had a significant main effect on perceived likelihood of threat from ocean acidification ($F_{(2,278)} = 7.50$, p

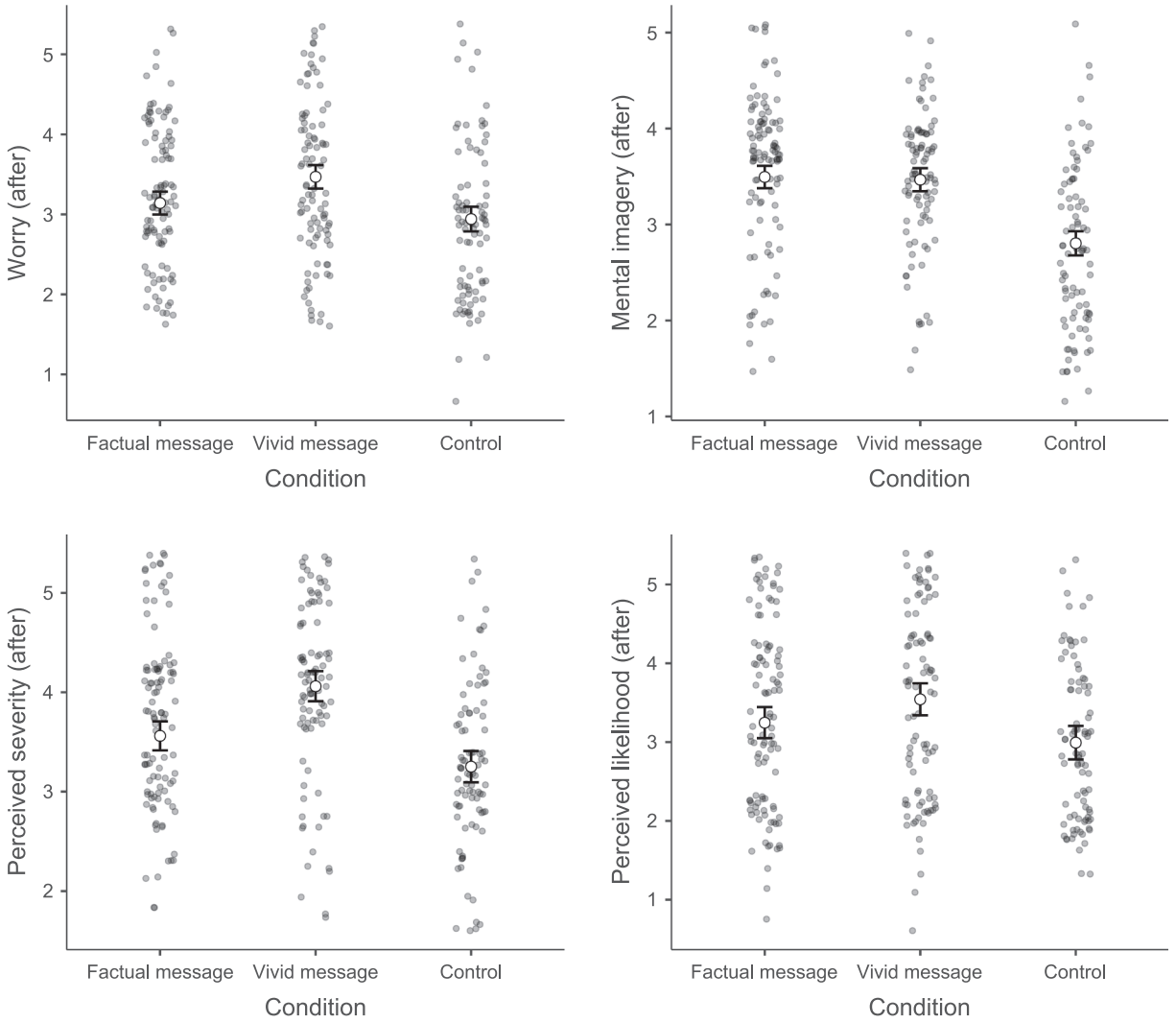

Fig. 2. Estimated marginal means plots for the outcome measures in Study 2 (UK sample). Shown are observed scores and 95% confidence intervals after exposure to the contents in each condition.

$<.001$, $\eta^2_{partial} = 0.05$). Here, we found that the perceived likelihood was significantly higher among those in the vivid message condition ($M = 3.54$, $SE = 0.10$) than among participants that were assigned to the control condition ($M = 2.99$, $SE = 0.11$, $p <.001$, $d = 0.58$). An additional set of post hoc tests indicated no significant differences in perceived likelihood of threat from ocean acidification if comparing participants who received the factual message ($M = 3.25$, $SE = 0.10$) with those who were either assigned to the vivid message condition ($p =.109$, $d = 0.31$) or the control condition ($p =.235$, $d = 0.27$).

The significant main effect of information exposure on mental imagery of ocean acidification was replicated ($F_{(2,277)} = 42.43$, $p <.001$, $\eta^2_{partial} = 0.24$; cf. Fig. 2). The factual message ($M = 3.50$, $SE = 0.06$, $p <.001$, $d = 1.23$) and the vivid message ($M = 3.47$, $SE = 0.06$, $p <.001$, $d = 1.18$) produced significantly greater mental imagery of ocean acidification than the control condition ($M = 2.80$, $SE = 0.06$). There was again no significant difference between the factual message condition and the vivid message condition in their respective ability to stimulate mental imagery about ocean acidification ($p = 1.000$, $d = 0.05$).

4. Discussion

Public comprehension of ocean acidification is integral to a constructive public discourse around major policy decisions and this comprehension is likely to be underpinned by basic awareness (Capstick et al., 2016). Compared to other marine-related climate issues, however, the increasing acidity of the ocean has received somewhat less attention in the public sphere. An investigation with samples from several European countries found that a vast majority of the respondents felt ill-informed about the topic, which was in contrast to issues such as arctic sea ice (Buckley et al., 2017). The data reported in this paper complements these findings by showing that only a small fraction in each sample reported high levels of knowledge about ocean acidification. When considering the multitude of potential risks associated with increased levels of acidity in the oceans, there remains a pressing need to increase public awareness on the topic.[6]

Studies from the UK and the US showed that confronting people with expository facts can help increase concern about ocean acidification over time (Capstick et al., 2016; Cooke and Kim, 2019). One noteworthy addition to the studies reported here was the incorporation of a control condition, which in turn provides a more robust assessment to detect the causal effects from information exposure. There was evidence for an overall effect of information exposure for each of the outcome measures addressed by this investigation. This means that providing people with information about ocean acidification significantly changes their perceptions and emotions regarding the issue. However, the style with which the information is presented also matters. Across two studies, we found that worry about ocean acidification is significantly heightened when information about ocean acidification is presented in vivid detail but not when plain facts about the issue are presented. Results for the two dimensions of ocean acidification risk perception were more nuanced. While the vivid message elicited heightened perceived severity of, and perceived likelihood of threat from, the risk posed by ocean acidification across two studies, the effects of the plain factual message were less consistent. A tentative interpretation of these results is that the provision of expository facts may have the capacity to increase risk perception in some contexts, but that the effectiveness of these messages may also be contingent on the target audience.

After *The Uninhabitable Earth* was initially published in 2017, the essay has been subject to some controversial debate. Whereas some have criticized it for providing an inaccurate depiction of the available scientific evidence (Mann et al., 2017; Mooney, 2017), others stressed its success in directing public attention towards the emerging climate crisis (Atkin, 2017). This investigation employed an excerpt from this essay as stimulus material in a vivid message condition, to confront the participants with visceral and dire language illustrating current and future effects of ocean acidification. Not only did we find support for a unique causal effect from this message on both risk perception and worry, it was also possible to replicate these effects across two different samples. This suggests that messages utilizing fear-provoking content can be harnessed to increase public engagement with ocean acidification, even in contexts where the exposition of simple facts remains insufficient to elicit changes in risk perception and worry. Research on environmental advertisements supports this interpretation by showing that messages including emotionalizing content can be a means to reach audiences that are otherwise unreceptive to factual information (Hoewe and Ahern, 2017).

Research into the reception of climate fiction shows that reading about a dystopian future after global warming can make the impacts from climate change appear as more concrete (Schneider-Mayerson, 2018). The current investigation found that exposure to information about ocean acidification made it easier for the participants to imagine possible causes and consequences, compared to a control condition, irrespective of the style with which the information was presented to them. This suggests that the differences in the effects of the plain and vivid information conditions in their effects on risk perception and worry about ocean acidification is not simply due to differences in the ability of these narrative styles to invoke clear mental imagery of the issue. Further research is necessary to explore other psychological mechanisms that may account for the observed differences in the effects of different messages on risk perception and worry toward ocean acidification.

It is notable that the number of those who had not heard about ocean acidification before was roughly three times higher in the UK (35.9%) than was the case in Norway (10.0%). These baseline differences in sample characteristics point towards a possible explanation for why effects of the factual message condition on risk perception varied across national contexts. Further research remains warranted to clarify the role of subjective knowledge in shaping how people react when they are presented with plain scientific descriptions of ocean acidification. This should ideally involve experimental designs that allow to assess and compare different approaches in framing messages about marine-related environmental issues; for instance, highlighting the severity of the problem versus

[6] The current (and projected) rates of ocean acidification may not just affect life in marine ecosystems, but can also have major implications for society and individuals, for instance via compromsing the quantitive availability and nutritonal quality of seafood (for a review of how ocean acidification may affect humans health and well-being, see Falkenberg et al., 2020).

emphasising possible solutions (Kolandai-Matchett and Armoudian, 2020).

5. Limitations

The current studies had some limitations. First, the samples were not representative, which means that any generalizations towards the public at large must be made with caution. This holds true notwithstanding the fact that levels of self-reported knowledge of ocean acidification among our participants were remarkably similar to studies based on nationally representative samples from the UK (Capstick et al., 2016; Spence et al., 2018). Second, this investigation detected changes in risk perception and worry immediately after the participants were exposed to short-written messages about ocean acidification. Further research is needed to determine the stability of these effects over longer time periods. For example, a study from the US found that reading climate fiction stories showed significant effects on people's attitudes and beliefs, but these effects decreased back to baseline one-month after exposure (Schneider-Mayerson et al., 2023). Third, it could be that the vivid description was more accessible to the participants, simply because this text was closer to everyday language. Replication attempts should incorporate measures on text readability to account for this possible factor.

6. Conclusion

Unabated global greenhouse gas emissions have led to unprecedented changes in global average temperatures, which already contributes to observed changes in weather and climate extremes in many regions across the world (IPCC, 2021). While media often relies upon vivid images of natural disasters, like flooding or hurricanes, less attention has been devoted to other possible manifestations of global warming. One of these manifestations is increased levels of acidity in the ocean, which, unless there are significant reductions in atmospheric CO_2 emissions, is expected to escalate over the course of the next decades (IPCC, 2021). The studies reported and discussed in this paper support a conclusion that presenting people with information about ocean acidification can enhance their risk perception and worry about the issue. Both outcome measures were sensitive to the vivid message, but for the factual message, the effects varied between samples. More research is needed to explore the psychological mechanisms that underlie the observed differences in how people's emotions and perceptions of ocean acidification are affected by exposure to plain or vivid information.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Ethics

Informed consent was obtained from all participants before the study. Ethics approval for Study 1 was not required as per institutional guidelines and regulations at the time of the data collection. Ethics approval for Study 2 was granted by the Research Ethics Committee at the School of Psychology, University of Nottingham (Ref: S1347).

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References

Atkin, E., 2017. The power and peril of "climate disaster porn." The New Republic. https://newrepublic.com/article/143788/power-peril-climate-disaster-porn.
Boykoff, M., Pearman, O., 2019. Now or never: How media coverage of the IPCC special report on 1.5°C shaped climate-action deadlines. One Earth 1 (3), 285–288. https://doi.org/10.1016/j.oneear.2019.10.026.
Breakwell, G.M., 2007. The Psychology of Risk. Cambridge University Press.
Brislin, R.W., 1970. Back-translation for cross-cultural research. J. Cross Cult. Psychol. 1 (3), 185–216. https://doi.org/10.1177/135910457000100301.
Brysse, K., Oreskes, N., O'Reilly, J., Oppenheimer, M., 2013. Climate change prediction: Erring on the side of least drama? Glob. Environ. Chang. 23 (1), 327–337. https://doi.org/10.1016/j.gloenvcha.2012.10.008.
Buckley, P.J., Pinnegar, J.K., Painting, S.J., Terry, G., Chilvers, J., Lorenzoni, I., Gelcich, S., Duarte, C.M., 2017. Ten thousand voices on marine climate change in Europe: Different perceptions among demographic groups and nationalities. Front. Mar. Sci. 4, 1–17. https://doi.org/10.3389/fmars.2017.00206.
Busselle, R., Bilandzic, H., 2009. Measuring narrative engagement. Media Psychol. 12 (4), 321–347. https://doi.org/10.1080/15213260903287259.
Capstick, S.B., Pidgeon, N.F., Corner, A.J., Spence, E.M., Pearson, P.N., 2016. Public understanding in Great Britain of ocean acidification. Nat. Clim. Chang. 6 (8), 763–767. https://doi.org/10.1038/nclimate3005.
Cooke, S.L., Kim, S.C., 2019. Exploring the "evil twin of global warming": Public understanding of ocean acidification in the United States. Sci. Commun. 41 (1), 66–89. https://doi.org/10.1177/1075547018821434.

Dannevig, H., Groven, K., Hovelsrud, G.K., Lundberg, A.K., Bellerby, R.G., Wallhead, P., Labriola, M., 2019. A framework for agenda-setting ocean acidification through boundary work. Environ. Sci. Policy 95, 28–37. https://doi.org/10.1016/j.envsci.2019.02.001.
De Groot, J.I.M., Steg, L., 2008. Value orientations to explain beliefs related to environmental significant behavior: How to measure egoistic, altruistic, and biospheric value orientations. Environ. Behav. 40 (3), 330–354. https://doi.org/10.1177/0013916506297831.
Dugard, P., Todman, J., 1995. Analysis of pre-test-post-test control group designs in educational research. Educ. Psychol. 15 (2), 181–198. https://doi.org/10.1080/0144341950150207.
Eddy, T.D., 2014. One hundred-fold difference between perceived and actual levels of marine protection in New Zealand. Mar. Policy 46, 61–67. https://doi.org/10.1016/j.marpol.2014.01.004.
Falkenberg, L.J., Bellerby, R.G.J., Connell, S.D., Fleming, L.E., Maycock, B., Russell, B.D., Sullivan, F.J., Dupont, S., 2020. Ocean acidification and human health. Int. J. Environ. Res. Public Health 17 (12), 4563. https://doi.org/10.3390/ijerph17124563.
Faul, F., Erdfelder, E., Buchner, A., Lang, A.-G., 2009. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behav. Res. Methods 41 (4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149.
Gruber, N., Clement, D., Carter, B.R., Feely, R.A., van Heuven, S., Hoppema, M., Ishii, M., Key, R.M., Kozyr, A., Lauvset, S.K., Lo Monaco, C., Mathis, J.T., Murata, A., Olsen, A., Perez, F.F., Sabine, C.L., Tanhua, T., Wanninkhof, R., 2019. The oceanic sink for anthropogenic CO 2 from 1994 to 2007. Science 363 (6432), 1193–1199. https://doi.org/10.1126/science.aau5153.
Hall-Spencer, J.M., Harvey, B.P., 2019. Ocean acidification impacts on coastal ecosystem services due to habitat degradation. Emerg. Top. Life Sci. 3 (2), 197–206. https://doi.org/10.1042/ETLS20180117.
Hoewe, J., Ahern, L., 2017. First-person effects of emotional and informational messages in strategic environmental communications campaigns. Environ. Commun. 11 (6), 810–820. https://doi.org/10.1080/17524032.2017.1371050.
IPCC, 2021. Summary for policymakers. In: Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., Zhou, B. (Eds.), Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Asessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, p. 42.
Jensen, B.B., 2002. Knowledge, action and pro-environmental behaviour. Environ. Educ. Res. 8 (3), 325–334. https://doi.org/10.1080/13504620220145474.
Koenigstein, S., Ruth, M., Gößling-Reisemann, S., 2016. Stakeholder-informed ecosystem modeling of ocean warming and acidification impacts in the Barents Sea region. Front. Mar. Sci. 3, 1–13. https://doi.org/10.3389/fmars.2016.00093.
Kolandai-Matchett, K., Armoudian, M., 2020. Message framing strategies for effective marine conservation communication. Aquat. Conserv. Mar. Freshwat. Ecosyst. 30 (12), 2441–2463. https://doi.org/10.1002/aqc.3349.
Kolandai-Matchett, K., Armoudian, M., Li, E., 2021. Communicating complex ocean issues: How strategically framed messages affect awareness and motivation when conveyed using narrative vs. expository language. Aquat. Conserv. Mar. Freshwat. Ecosyst. 31 (4), 870–887. https://doi.org/10.1002/aqc.3484.
Kroeker, K.J., Kordas, R.L., Crim, R.N., Singh, G.G., 2010. Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. Ecol. Lett. 13 (11), 1419–1434. https://doi.org/10.1111/j.1461-0248.2010.01518.x.
Loewenstein, G.F., Weber, E.U., Hsee, C.K., Welch, N., 2001. Risk as feelings. Psychol. Bull. 127 (2), 267–286. https://doi.org/10.1037//0033-2909.127.2.267.
Mabardy, R.A., Waldbusser, G.G., Conway, F., Olsen, C.S., 2015. Perception and response of the U.S. West Coast shellfish industry to ocean acidification: The voice of the canaries in the coal mine. J. Shellfish. Res. 34 (2), 565–572. https://doi.org/10.2983/035.034.0241.
Mann, M. E., Hassol, S.J., Toles, T., 2017. Doomsday scenarios are as harmful as climate change denial. The Washington Post. https://www.washingtonpost.com/opinions/doomsday-scenarios-are-as-harmful-as-climate-change-denial/2017/07/12/880ed002-6714-11e7-a1d7-9a32c91c6f40_story.html.
Mooney, C., 2017. Scientists challenge magazine story about “uninhabitable Earth”. The Washington Post. https://www.washingtonpost.com/news/energy-environment/wp/2017/07/12/scientists-challenge-magazine-story-about-uninhabitable-earth/?noredirect=on&utm_term=.f711ac1722d9.
O’Connor, R.E., Bord, R.J., Fisher, A., 1999. Risk perceptions, general environmental beliefs, and willingness to address climate change. Risk Anal. 19 (3), 461–471. https://doi.org/10.1111/j.1539-6924.1999.tb00421.x.
Oakes, J.M., Feldman, H.A., 2001. Statistical power for nonequivalent pretest-posttest designs: The impact of change-score versus ANCOVA models. Eval. Rev. 25 (1), 3–28. https://doi.org/10.1177/0193841X0102500101.
Ogunbode, C.A., Doran, R., Böhm, G., 2020a. Exposure to the IPCC special report on 1.5 °C global warming is linked to perceived threat and increased concern about climate change. Clim. Change 158 (3–4), 361–375. https://doi.org/10.1007/s10584-019-02609-0.
Ogunbode, C.A., Doran, R., Böhm, G., 2020b. Individual and local flooding experiences are differentially associated with subjective attribution and climate change concern. Clim. Change 162 (4), 2243–2255. https://doi.org/10.1007/s10584-020-02793-4.
Raven, J., Caldeira, K., Elderfield, H., Hoegh-Guldberg, O., Liss, P., Riebesell, U., Shepherd, J., Turley, C., Watson, A., 2005. Ocean acidification due to increasing atmospheric carbon dioxide. The Royal Society. https://royalsociety.org/topics-policy/publications/2005/ocean-acidification/.
Sabine, C.L., Feely, R.A., Gruber, N., Key, R.M., Lee, K., Bullister, J.L., Wanninkhof, R., Wong, C.S., Wallace, D.W.R., Tilbrook, B., Millero, F.J., Peng, T.-H., Kozyr, A., Ono, T., Rios, A.F., 2004. The oceanic sink for anthropogenic CO_2. Science 305 (5682), 367–371. https://doi.org/10.1126/science.1097403.
Schneider-Mayerson, M., 2018. The influence of climate fiction. Environ. Humanit. 10 (2), 473–500. https://doi.org/10.1215/22011919-7156848.
Schneider-Mayerson, M., Gustafson, A., Leiserowitz, A., Goldberg, M.H., Rosenthal, S.A., Ballew, M., 2023. Environmental literature as persuasion: An experimental test of the effects of reading climate fiction. Environ. Commun. 17 (1), 35–50. https://doi.org/10.1080/17524032.2020.1814377.
Sjoberg, L., 1998. Worry and risk perception. Risk Anal. 18 (1), 85–93. https://doi.org/10.1111/j.1539-6924.1998.tb00918.x.
Slovic, P., 1999. Trust, emotion, sex, politics, and science: Surveying the risk-assessment battlefield. Risk Anal. 19 (4), 689–701. https://doi.org/10.1111/j.1539-6924.1999.tb00439.x.
Smith, N., Leiserowitz, A., 2014. The role of emotion in global warming policy support and opposition. Risk Anal. 34 (5), 937–948. https://doi.org/10.1111/risa.12140.
Spence, E., Pidgeon, N., Pearson, P., 2018. UK public perceptions of Ocean Acidification – The importance of place and environmental identity. Mar. Policy 97, 287–293. https://doi.org/10.1016/j.marpol.2018.04.006.
Stathi, S., Crisp, R.J., 2008. Imagining intergroup contact promotes projection to outgroups. J. Exp. Soc. Psychol. 44 (4), 943–957. https://doi.org/10.1016/j.jesp.2008.02.003.
Sundblad, E.-L., Biel, A., Gärling, T., 2007. Cognitive and affective risk judgements related to climate change. J. Environ. Psychol. 27 (2), 97–106. https://doi.org/10.1016/j.jenvp.2007.01.003.
Wallace-Wells, D., 2017. The Uninhabitable Earth. New York Magazine. https://nymag.com/intelligencer/2017/07/climate-change-earth-too-hot-for-humans.html.
Wang, S., Leviston, Z., Hurlstone, M., Lawrence, C., Walker, I., 2018. Emotions predict policy support: Why it matters how people feel about climate change. Glob. Environ. Chang. 50, 25–40. https://doi.org/10.1016/j.gloenvcha.2018.03.002.
Zaleskiewicz, T., Traczyk, J., Sobkow, A., 2023. Decision making and mental imagery: A conceptual synthesis and new research directions. J. Cogn. Psychol. 1–31 https://doi.org/10.1080/20445911.2023.2198066.