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Individual perceptions of climate anomalies and collective action: Evidence from an artefactual field experiment in Malaysian Borneo

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Individual perceptions of climate anomalies and collective action: Evidence from an artefactual field experiment in Malaysian Borneo

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A R T I C L E I N F O

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A B S T R A C T

We explore the effect of individual perceptions of climate anomalies on collective action within a context of environmental complexity and uncertainty. To do so, we construct two competing propositions that are theoretically robust but with very different real-world implications. Our first proposition suggests that collective action to adapt to climate change is likely to be more effective when perceptions of climate anomalies converge within a community. Our second proposition suggests the opposite: that convergence is likely to hinder adaptation behaviour. We use a community co-designed measure of perceptions and an artefactual field experiment to test our propositions and explore the effect of perception convergence on climate change adaptation behaviour in six communities in Malaysian Borneo. We find a robust positive relationship between convergent perceptions of climate anomalies and the collective action required to adapt to climate change. Our findings suggest that perception convergence is an underexplored and potentially crucial factor that can either drive or hinder adaptation efforts at the community-level.

1. Introduction

Climate anomalies – defined as significant deviations from the norm – play a critical role in shaping individual adaptation behaviour [43,51]. Theoretically, we can expect climate anomalies, which often manifest as extreme weather events, to act as focusing events that communicate the local impacts of climate change to individuals [86]. This, in turn, may translate into changes in an individual's climate change adaptation behaviour through a process of Bayesian updating, with the anomaly experience serving as new information that allows an individual to update their climate change adaptation behaviour [22,24,51,66].[1] How individual perceptions of climate anomalies translate into the collective, however, is not clear. This is an important gap in the literature as we can expect that an individual's perceptions of climate anomalies are likely to be affected by a range of factors, including shifting baseline syndrome [30,69], change blindness [2,81] and memory illusions [18]. These factors are likely to result in a scenario where individuals within a community have different perceptions of the occurrence and magnitude of climate anomalies [105].

Drawing on insights from the wider collective action literature, we explore the effect of individual perceptions of climate anomalies on collective action within a context of environmental complexity and uncertainty. We construct two competing propositions which, though theoretically robust, result in very different real-world implications. Our first proposition suggests that community-level adaptation to climate change is likely to be more effective when perceptions of climate anomalies converge. This proposition is based on the position that groups can more effectively adapt when members are able to adjust common beliefs. Our second proposition suggests that converging perceptions may hinder collective adaptation because the norms that ensure within-group homogeneity also prevent information about environmental change from being acknowledged.

While there are many complex barriers to community-level adaptation to climate change [1,39,57,65,67,68,78,79], we focus on what we consider to be an underexplored and potentially crucial driver of climate change adaptation: collective perceptions of climate anomalies. Specifically, we are interested in exploring how convergent and divergent individual perceptions of climate anomalies affect collective action and climate change adaptation behaviour. To do so, we use an artefactual field experiment undertaken in six Indigenous communities in Malaysian Borneo to empirically test our two competing propositions.

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[1] Howe [43] and Howe et al. (2019) suggest that a key limitation of existing empirical studies is their inability to randomly assign individuals to experience climate anomalies. Notwithstanding this limitation, a number of studies provide empirical support of this process (e.g., Spence et al. [96], Akerlof et al. [97], Borick et al. [98], Reser et al. [99], Knoisky et al. [100], Demski et al. [101], Ray et al. [102]).

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Our experiment is built around a community co-designed measure of climate anomalies [105] and the collective risk social dilemma (CRSD) framework [60,10,17,83,13,28,89,90]

The remainder of our paper is as follows. In Section 2, we draw on the collective action literature to construct our theoretical propositions on perceptions of climate anomalies and collective climate change adaptation behaviour. In Section 3, we describe our experimental design and analytical methods. In Section 4, we present our experimental findings. In Section 5, we discuss our findings and contextualise their contribution to the literature. We conclude in Section 6.

2. Individual perceptions of climate anomalies and collective adaptation behaviour

We draw on two main strands of research that offer important insights into the processes that connect individual perceptions with collective action in groups. Built around the notion of a 'mental model', the first strand of literature considers shared perception of the environment as essential to any group-level action that requires coordination among members [74]. To navigate a changing environment characterised by noise and uncertainty, individuals internally create heuristics of the outside world to help them focus on the few crucial factors that drive relevant outcomes and map them to causal processes of interest [62]. At the individual level, simplifying the external environment through heuristics allows for more reliable predictions to be made at relatively low cognitive and informational cost [50]. At the group level, Denzau and North [19] and Roy and Denzau [74] argue that the more members share the same mental model, the more effectively predictions are aggregated to guide group responses to situations that are too complex for any given individual to engage with.

Access to shared perceptions is particularly critical under high environmental uncertainty, which is a common challenge in adaptive situations [20,82]. With convergent perceptions, information about changes in the environment can be exchanged and aggregated rapidly as group members seek to explain the emerging data and calibrate their collective response. Shared mental models give group members access to preexisting concepts to describe perceived reality to one another, overcoming a general communication problem that besets speaker and listener and precludes explicit analysis and direct learning [14,41].

In adaptive scenarios such as climate change, groups must be able to describe climate anomalies and communicate with others about them to coordinate adaptive responses [70]. From increased variance in rainfall to the overall increase in average temperatures, the increased frequency and severity of climate anomalies attributable to climate change mean that previous historical patterns of human-environment interaction will radically change [71,77]. Effective responses to these changes will require perceptions that can adapt to continuous change and evolve through learning [48]. Communities where perceptions of climate anomalies are aligned are therefore more capable of learning about new changes and deciding what they can do collectively. For communities where perceptions are more heterogeneous, these activities are expected to incur inhibitive costs in learning and interpretation.

Proposition 1. Shared perceptions of climate anomalies are associated with more effective climate change adaptation. Adaptation to climate change is less effective the greater the heterogeneity of perceptions within a community.

The second strand of research is based on the groupthink thesis and suggests that individuals sharing convergent ideas about the environment are less receptive to evidence that contradicts propositions shared by the group they belong to [38,46]. Compared with confirmatory bias and information avoidance at the individual level [25], groupthink creates persistent bias at the group level. It resembles a 'social contagion,' where the group's cohesiveness itself becomes intrinsically valuable to individual members, motivating them to strive for unanimity on issues, supress doubts and follow the group leader [5]. These strictures of conformity drive out more rational assessment of risk, thereby limiting behavioural adjustment due to the threat it would pose for long-held beliefs and the social order in which these beliefs are embedded. Highly cohesive groups tend to prevent these outcomes by creating an informational closed circuit which filters out information that does not reinforce existing beliefs [31,73].

This problem manifests itself potently in collective action scenarios where the community faces high uncertainty. Although the community may have extensive knowledge of the system, emerging anomalies associated with climate change are likely to remain outside the community's shared perceptions. Communities with high levels of perception convergence may therefore even explicitly dismiss clear signs indicative of climate change as aberrations. Further, groupthink appears to escalate in the presence of major threats imposed externally, such as extreme weather events. Groups facing high stress may exhibit information avoidance, where they severely underestimate or ignore unfavourable signals while taking an overly optimistic view of favourable signals. A vicious cycle may follow in that group-level mischaracterisation of climate anomalies is reinforced by the stress they create, leading to even more severe information avoidance, which in turn further reduces the group's capacity for adaptation [3].

Proposition 2. Perception heterogeneity is associated with more effective climate change adaptation. As group perceptions of climate anomalies converge, we can expect climate change adaptation behaviour to become less effective.

Our propositions capture two contrasting positions offered by the literature. The first proposition suggests that groups can coordinate adaptation better for complex problems and in greater uncertainty when members share convergent perceptions to adjust common beliefs and coordinate collective choices. The second proposition argues that the very convergence of perceptions will likely make adaptation behaviour less effective because the norms that ensure within-group homogeneity also prevent information about environmental change from being acknowledged. Taken together, whether communities with convergent perceptions of climate anomalies will adapt more effectively to climate change than those with more divergent perceptions remains theoretically contested.

3. Methods

3.1. Study sites

Our study sites consisted of six Penan communities located in the Baram region of Sarawak: Long Urang, Long Jenalong, Long Kerangan, Long Leng, Long Latei and Long Win (see Fig. 1). The Penan are one of the main Indigenous groups[2] in Malaysian Borneo and have an unparalleled knowledge of the Borneo rainforest [36,88,95],[3] which is central to many of the customs and traditions of the Penan. For example, younger males undertake a journey (known in the Penan language as *Toro*), during which elders pass on their traditional knowledge of the rainforest and their values of forest stewardship to the younger generation [80,88,95]. Formerly nomadic, the six communities we study were settled in the 1950s through 1970s, a period in which 97% of the general Penan population shifted to semi-nomadic and settled lifestyles [12,53], 109]. As of 2020, populations ranged from between 150 individuals (40 households) in Long Win to 340 individuals (89 households) in Long Latei. All six communities are connected to Long Bedian, the nearest town, through a network of unpaved logging roads.

[2] Around 40% of Sarawak's population are legally classified as Indigenous (Nelson et al.[103]; Minority Rights Group International, [104]), with many living in remote communities deep in the interior [88].

[3] For example, the Penan draw on over 200 sources of food, 300 types of construction materials and 90 kinds of medicinal herbs from the rainforest [49].

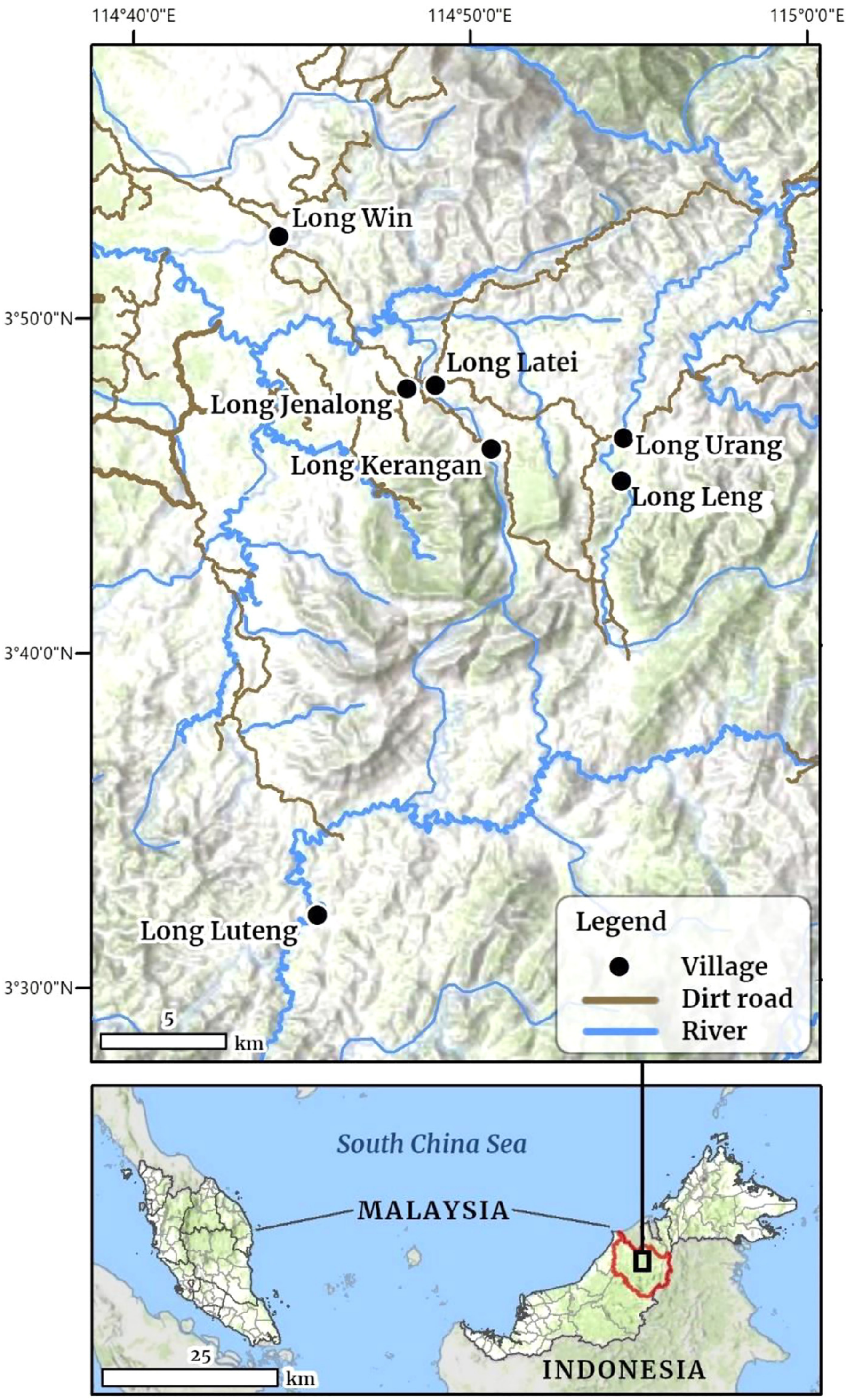

Fig. 1. Study sites.

3.2. Measuring perceptions of climate anomalies

The research team worked with elders in Long Luteng, a Penan community similar to our six field sites but located sufficiently far away to preclude spillovers occurring (see Fig. 1), to co-design a vehicle to measure perceptions of climate anomalies (see [105] for more details). Conceptually, our measure was based on a robust and verified statistical measure of climate anomalies (see, for example [44,51,54,72,76]). Our measure can be described by the following equation:

$$a_{i,t} = \frac{X_{i,t} - \mu_i}{\sigma_i} \quad (1)$$

where $a_{i,t}$ indicates the presence of a climate anomaly (e.g., flooding, drought) in area i in period t. $X_{i,t}$ represents the climate variable (e.g., rainfall) as measured in area i in period t and μ_i represents the long-term mean of the climate variable in area i. Typically, an area is defined to have experienced a climate anomaly in period t if the deviation in the climate variable for period t is at least one standard deviation away from the long-term mean.

In response to anecdotal reports by community members concerning the increased prevalence and devastating impacts of flooding and drought in our Penan communities, we focused on rainfall anomalies as our measure of climate anomalies. To increase recall accuracy, we constructed our measure based on the four seasons around which the Penan structure their activities: two dry seasons (January-February and August-September) and two wet seasons (March-July and October-December). Collaborative discussions with community elders led us to use river levels as a proxy measure for rainfall for several reasons. First, the Penan have excellent recall ability of river levels as rivers are used as reference points when navigating the rainforest [36,93,94]. Second, all six communities are located adjacent to a tributary of the Baram river, meaning that any change in river levels is highly salient.[4] Third, visual inspection of Landsat images over 9-year intervals from 1998 to 2015 and forest cover loss data [37] showed negligible upstream logging, suggesting that there was little possibility that river levels may have been affected by external events, such as upstream logging. (see [citation retracted]).

Our community co-designed method to measure perceptions of river levels can be described as follows. Individual respondents were shown seven identical one-liter water bottles each filled to a different level to represent river levels. For each season, we asked respondents to select the bottle (on a 1–7 scale) that they thought corresponded best to what they considered the normal (long-term average) river level. For each season, we proceeded to ask respondents to select bottles corresponding to what they perceived river levels to have been over a period of three years. These selected bottles were then compared with the bottles that respondents had chosen to represent normal river-levels for each season. We defined respondents to have perceived a rainfall anomaly in a given season if their chosen bottle was at least one level below or above the bottle they chose to represent the normal river level. Over a two-month period (June-August) in 2018, we measured the perceptions of climate anomalies of 200 individuals spread across the six communities (see [105] for a detailed discussion on the robustness of our measure and for a detailed analysis of the anomaly perception data).

3.3. Experimental design

We are interested in isolating the effect of convergent perceptions of climate anomalies on climate change adaptation behaviour at the community level. To do so, we consider it important to generate observable adaptation behaviour rather than, for example, relying on stated responses collected through survey questionnaires or other data collection protocols. This is as stated behavioural responses may be subject to a number of response biases, including social desirability and acquiescent responses [55]. We therefore elected to use an artefactual field experiment, which allows us to observe adaptation behaviour that otherwise would be difficult to identify and is not likely to be subject to response biases [4]. Artefactual field experiments consist of conducting a laboratory experiment (in terms of using a standardised and validated lab paradigm) in a field setting.[5] By maintaining the highly controlled structure of a laboratory experiment and drawing a sample that is representative of the population of interest, artefactual field experiments can produce results that are both internally and externally valid [34].

Our experimental design required the random assignment of individuals into two groups: a group with convergent perceptions of climate anomalies and a group with non-convergent perceptions. By randomly assigning individuals to groups, we were able to use randomisation as an identification strategy. For both convergent and non-convergent groups, we used the CRSD framework to generate observable climate change adaptation behaviour [60,61]. The CRSD framework has been extensively used in the experimental climate change literature due to its ability to resemble the real world while maintaining a rigorous experimental set-up. Specifically, the CRSD framework maintains key stylised features of climate change adaptation such as collective action dynamics, multi-round duration, and threshold dynamics while generating clearly observable behavioural data at the individual and group levels [10,17,60,61,83,13,28,89].

Operationalised as a modified threshold public goods game, the CRSD framework generates data points representing an individual's climate change adaptation behaviour through having individuals decide whether to keep an endowment for themselves or to allocate it to a common climate account that will be used to support adaptation activities in the real-world. Importantly, these decisions occur over multiple rounds in a group setting and with a predefined threshold value, which must be cumulatively reached by the end of the game. Otherwise, individuals face the possibility of losing their own endowment. While a simplification of reality, the CRSD framework maintains key stylised features of climate change adaptation while presenting us with clearly observable behavioural data.

3.4. Structure of the experiment

Our Sarawak-based co-author and a Penan research assistant visited each community in late 2020 to undertake the experiment.[6] Upon arriving at each community, we demonstrated the experiment to the village leader and Elders by first running it with a non-randomly selected group of four village Elders. Every measure was taken to ensure that other members of the community were not present and that there were no spillovers. With the assistance of the Elders, we proceeded to draw up a list of individuals who were presently residing in each community. We cross-referenced this list with the list of 200 individuals for which the research team had collected data on perceptions of climate anomalies during previous fieldwork (see [105]). For each community, the number of individuals who were both present and for whom we had data on their perceptions of climate anomalies was between 15 and 20. This sample size limited the number of groups that we could form. As such, we chose to randomly select 12 individuals in each community to participate. These 12 individuals were randomly assigned to one of three groups: one group with convergent perceptions of climate anomalies (the treatment group) and two groups with non-convergent perceptions of climate anomalies (the control group). Each group consisted of four individuals.

Our experiment was structured as follows. First, individuals in both treatment and control groups were given a graphical representation of their previously recorded perceptions of climate anomalies for the second dry season (August-September) over a period of three years along with a verbal explanation of the graphic.[7] The explanation served to

[4] Village names illustrate the intimate relationship between the Penan and rivers. For example, Long Jenalong means 'the River Jenalong' in the Penan language.

[5] Artefactual field experiments are increasingly commonly used in developing countries due to their ability to estimate parameters that otherwise would be difficult (and arguably unethical) to identify [4,32]). Some examples in the literature include Bouma et al. [8], Melesse and Cecchi [58], Meriggi and Bulte [59], Ngoma et al. [63], Nie et al. [64], Hoenow and Kirk [40], Turpie and Letley [85].

[6] Our study was severely delayed by the COVID-19 pandemic and associated domestic and international travel restrictions. As a result, the overseas based authors were unable to be present for the experiment and the Sarawak-based research team were significantly delayed in undertaking the experiment. Every precaution was taken to carry out the research in a safe manner and all community, regional and national regulations were abided by.

[7] We made the decision to focus only on the second dry season for two reasons. First, our experiment took place in the period following the end of the dry season in 2020, thereby improving reliability and recall ability. Second, according to

reintroduce the co-designed measure of climate anomalies to participants and facilitate individual understanding of the graphical representations of their perceptions. Individuals in our treatment group proceeded to engage in a group discussion among themselves that was facilitated by our Sarawak-based research team in the Penan language. The discussion was structured to allow each individual the opportunity to share their recorded perceptions of anomalies and to explain their reasoning as to why they perceived rainfall to have been anomalous or normal during the given period. Next, the group discussed individual perceptions extensively until they were able to agree upon a shared perception of rainfall anomalies. Every effort was made to foster an inclusive discussion and allow each individual to speak. The control group did not engage in a discussion with other members.

Both treatment and control groups continued to participate in a modified threshold public goods game. In our game, each participant was endowed with RM40 (US$10). Each game was played over a period of ten rounds and in groups of four players. In each round, each player had the option to contribute between RM0 to RM4 (US$0 to US$1) in incremental amounts of RM1 (US$0.25) into a general community fund for climate change adaptation. This is a real-world fund vested in the general community that is exclusively used to finance future costs of adapting to the impacts of climate change.[8] In each round, individuals made their contributions anonymously and simultaneously.[9] At the end of the ten rounds, the total amount in the fund had to be at least RM80 (US$20).[10] If the threshold value was reached, individuals kept the remaining endowment, which they did not have to contribute to the fund. For example, if an individual contributed half their endowment (RM20) and the threshold value was met, the individual kept the remaining RM20 as their individual payoff. This represented a scenario in which the community took sufficient action to adapt to the local impacts of climate change. If the threshold value was not reached, there was around a 50% probability (simulated using a real-world coin toss) that the individual lost their remaining endowment.[11] This represented a scenario where insufficient action had been taken to adapt to climate change. During the game, at the end of each round, individuals were told how much had been contributed to the fund and how much remained to be contributed in order to meet the threshold value.

3.5. Adherence to Penan-researcher codified protocols

Members of the research team have a long-standing relationship with many Penan communities in Sarawak, including the communities of Long Luteng, Long Urang, Long Jenalong, Long Kerangan, Long Leng, Long Latei and Long Win. A key outcome of this relationship has been the co-generation of a set of researcher-community protocols designed, among other considerations, to ensure the co-generation of knowledge and fair and equitable use of any research outcomes. In this research project, we adhered to all 17 practices in the written protocol [27,33].[12] These include, among others, protocols on research initiation, goals and knowledge rights, equality, trade-offs, misapprehension, and mutual exchange.

Starting with research initiation, members of the research team communicated all project details with village leaders and Elders. Research goals and the recognition of mutual benefit were discussed in depth with village Elders. In turn, as much information about the project was communicated to community members as possible while ensuring that the data generated by the public goods game would not be invalidated. Approval for the research project was given by village Elders after receiving unanimous agreement from community members. This process is in line with the egalitarian governance structure of most Penan communities. To ensure equality between the Penan and researchers during the process, the research team clearly set out the objectives of the research study and the data requirements needed. Design of the climate anomaly measure and calibration of the public goods game constituted a collaborative process, with continuous dialogue ensuring mutual agreement. The Penan research protocols stress that if researchers make use of the time and effort of community members, they should be compensated appropriately. This is considered fair as time spent engaging with researchers is often at the expense of time spent on livelihood activities. To this end, the creation of a community fund and the setting of endowment amounts were designed to ensure that individuals and communities participating in the experiment were fairly compensated. Constant dialogue at all stages of the research project was maintained between village Elders and the research team to ensure that researcher interpretations of results were not misinterpreted due to, for example, culturally bounded thinking. This ongoing dialogue and iterative, co-designed research process also helped ensure that the findings of the research study were communicated effectively to the communities that made this work possible.

3.6. Estimation strategy

Our strategy for isolating the effect of convergent perceptions of climate anomalies on adaptation behaviour consisted of two parts. First, we analysed time trends between the treatment and control groups. We elected to use a measure of distance of contributions from a reference point to analyse time trends [28]. Our reference point is the fair contribution per round (RM2) – the amount that each individual needs to pay in per round to meet the threshold value collectively. Our distance from the reference point is calculated as follows:

$$d_{g,i,t} = \sum_{\tau=1}^{t} c^{\tau}_{g,i} - 2t \tag{1a}$$

where $d_{g,i,t}$ denotes the distance from the reference indexed by group, individual and round and $c^{\tau}_{g,i} \in \{0,1,2,3,4\}$ represents the monetary contribution of individual i in round τ. 2 represents our fair reference amount (RM2) for each round. In addition to visual inspection, we ran a Wilcoxon Rank Sum Test to test if differences in contributions – our measure of climate change adaptation behaviour – between our treatment and control groups are statistically significant.

Second, to account for the dynamic nature of the game, we estimated a mixed effects regression model to isolate the treatment effect on individual contributions to the climate change adaptation community fund. Our model takes the following form:

$$c_{g,i,t} = \alpha_0 + \beta_1 T_{g,i} + X'_{g,i}\Phi + R_t + R_t^2 + V_g + V'_{g,i} + \varepsilon_{g,i,t} \tag{2}$$

where $c_{g,i,t}$ represents individual contributions to the village fund, $T_{g,i}$ represents shared perceptions of climate anomalies, and $X'_{g,i}$ is a vector of individual-level control variables, including age, gender, education, livelihood strategy, salience of climate change, traditional ecological knowledge, and an asset index.[13] R_t and R_t^2 capture fixed effects

meteorological data, over the three-year period for which perceptions of rainfall anomaly data were collected, the second dry season consistently exhibited levels of rainfall that were between one to two standard deviations below the long-term mean (see 109).

[8] The fund was created as part of a collaborative process with village elders.

[9] Each participant was seated around 3 metres away from each other on chairs positioned so that participants had their backs turned to each other. Contributions were made physically into a covered moneybox that was brought to each participant in each round by the research team.

[10] Following Milinski et al. [60,61], among others, we set the threshold value to be equivalent to having all participants allocating RM2 (US$0.5) per turn – or half of their endowment – into the fund.

[11] Any amount lost as a result of the coin-toss were allocated to the community fund.

[12] Ethical approval to undertake this research study was further obtained from the lead author's institution.

[13] To account for treatment effect heterogeneity, we included a number of control variables that are theoretically linked with climate change adaptation be-

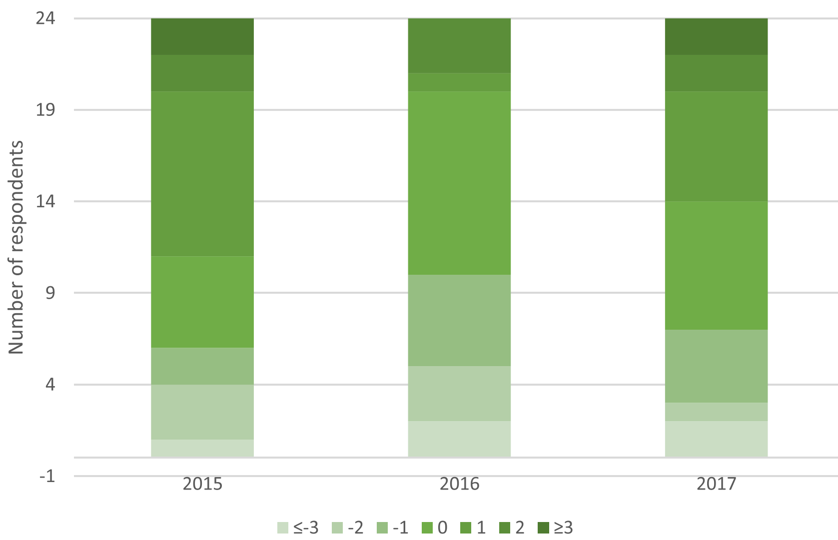

Fig. 2. Perceptions of climate anomalies in the treatment group (in terms of magnitude).

to account for the non-linear common time-trend and V_g and $V'_{g,i}$ represent random effects at the group and individual levels. We estimated our model using mixed effects to account for the nested structure and complexity of our experimental data. We fitted the data to our model using a Bayesian framework with vague priors due to its ability to estimate a mixed-effects model with data generated from a relatively small sample with precision and without losing power [56,87,91], and in order to compare the strength of evidence in support of our findings [6,7,15,26,16,28,35,47].

4. Results

A total of 72 individuals participated in our experiment. Individuals were randomly assigned to 18 groups – 12 control groups (non-convergent perceptions of climate anomalies) and 6 treatment groups (convergent perceptions of climate anomalies) – distributed equally across the six communities. Individual perceptions of rainfall anomalies for the second dry season over the three-year period varied for both the treatment and control group in terms of both occurrence and magnitude. For both groups, individual perceptions ranged from positive and negative deviations of over three levels to no perceived deviation from the long-term average (see Figs. 2 and 3). To test for a systematic association between individual perceptions of rainfall anomalies and group-type (control and treatment), we ran Fisher's exact tests for each year and in total. We found no statistically significant association, which suggests that our selection of control and treatment groups did not result in systematic bias ($p = 0.151$ in 2015; $p = 0.234$ in 2016; $p = 0.397$ in 2017; $p = 0.243$ in total).

From our 18 groups, all but one group met the threshold value. The group that did not meet the threshold value was from the control group (non-convergent perceptions of climate anomalies) and contributed a total of RM75, which was just RM5 short of the threshold. The average group contribution for our control groups was RM95 (std. dev. 12.292) and the average contribution for our treatment groups was RM113 (std. dev. 17.626). Fig. 4 presents an overview of average group contributions for control and treatment groups over the 10 rounds of our public goods game. Following Farjam et al. [28,29], we present our general time trend of contributions in terms of the distance from the reference contribution. This allows greater clarity in seeing how individuals made their repeated decisions relative to presenting contributions at face value. The reference contribution refers to the RM2 each individual in each group needed to contribute during each round to meet the threshold value. It is evident that while both groups exhibited a positive distance from the reference contribution, average contributions were substantially greater in our treatment groups than in our control groups. The difference in contributions between treatment and control groups was found to be statistically significant at the 5% level when running a Kruskal-Wallis Rank Sum Test ($p = 0.013$).

To further test whether convergent perceptions of climate anomalies led to higher contributions, we ran a mixed effects linear regression with individual contributions to the fund as the dependent variable. To fit our data to the model, we used a Bayesian framework with vague priors, with sampling involving two independent chains of 5000 + 5000 samples each. As shown in column 1 of Table 1, our coefficient of 0.46 and our 95% credible interval [0.010; 0.83] indicate that convergent perceptions of climate anomalies had a positive effect on individual contributions to the climate change adaptation fund. Calculating the posterior probability further shows that the probability that convergent perceptions have a positive effect on individual contributions relative to non-convergent perceptions is almost certain (0.99). Similarly, our Bayes Factor of 95.15 suggests that our findings are robust [47]. Our findings hold in column 2, which includes a range of control variables that theoretically may have affected individual contributions such as age, gender, education, livelihood strategy, salience of climate change,

Table 1
Mixed-effects regression estimations.

	(1)	(2)
Treatment	0.46	0.46
95% Credible Interval	[0.10, 0.83]	[0.07, 0.84]
Posterior Probability	0.99	0.99
Bayes Factor	95.15	97.04
Controls	No	Yes

Notes: Coefficient estimates for individual contributions to the community climate fund. Posterior probability and Bayes Factor values correspond with $H_o < 0$. Controls include age, gender, education, livelihood strategy, salience of climate change, a measure of traditional ecological knowledge, and an asset index. We include fixed effects for round and round squared and random effects at the individual and group levels. We fit the data to our model by using a Bayesian framework with vague priors. Sampling involved two independent chains with 5000 + 5000 samples each.

haviour [21,23,45,51,75]. These data were collected as part of the original data collection exercise in 2018 (see [105]).

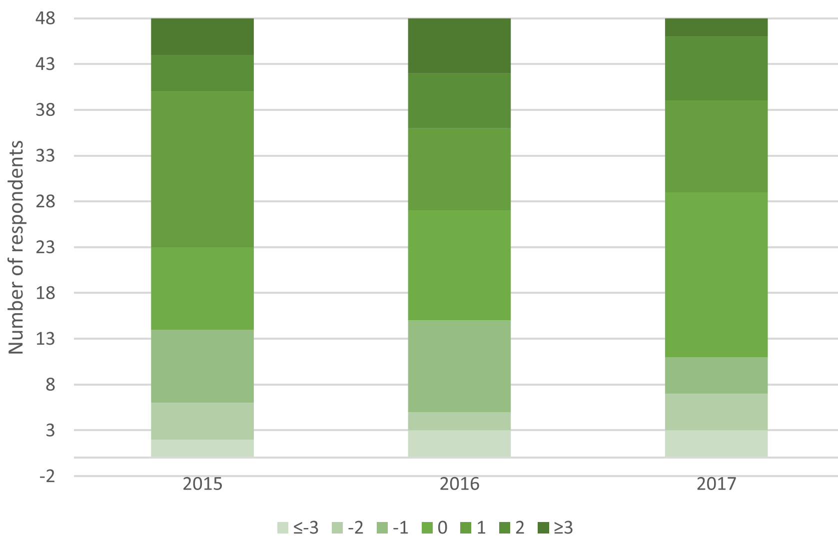

Fig. 3. Perceptions of climate anomalies in the control group (in terms of magnitude).

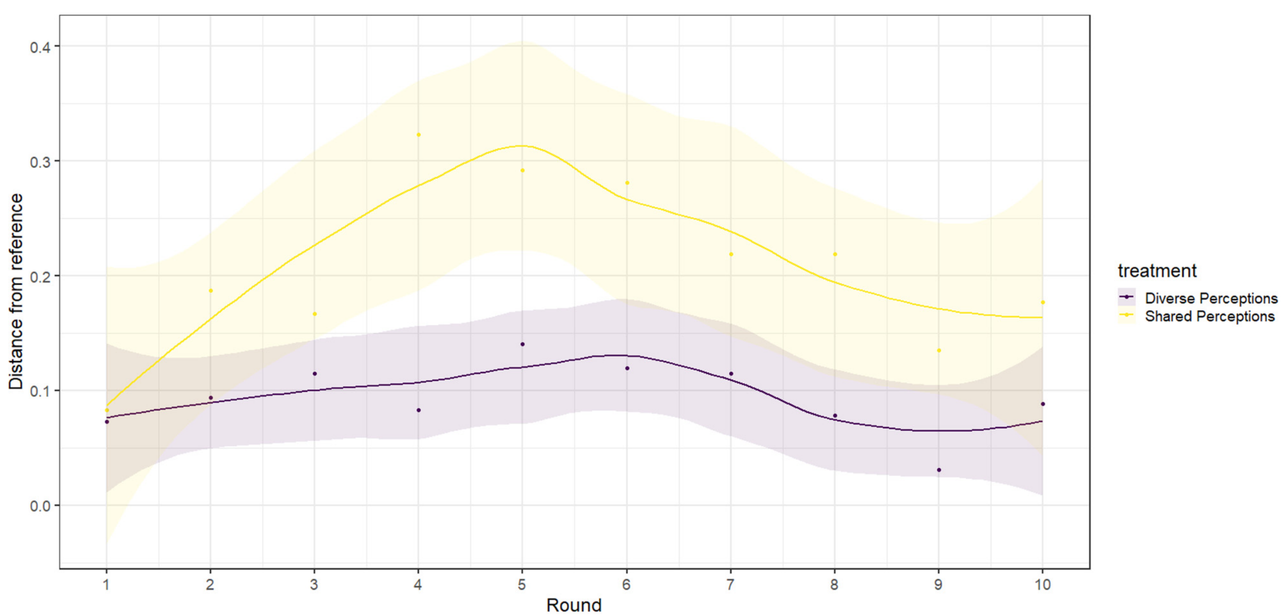

Fig. 4. Distance of individual contributions from reference with 95% confidence bands.

a measure of traditional ecological knowledge, and an asset index (see supplementary Table S1 for a data glossary). When our control variables are included, we continue to find a robust positive association between convergent perceptions and individual contributions with a posterior probability of 0.99 and a Bayes Factor of 97.04.

5. Discussion

Our experiment is premised on the idea that climate anomalies are an underexplored and potentially crucial driver of climate change adaptation among Indigenous communities in Malaysian Borneo and elsewhere. Specifically, we suggest that climate change adaptation behaviour may be at least partially dependent on perceptions of climate anomalies and how perceptions drive or inhibit the collective action required to adapt. Engaging with the broader collective action literature, we identify two streams of thought that generate two theoretically contestable propositions. The first proposition suggests that groups with convergent perceptions of climate anomalies should be able to better coordinate collective action choices, as they are able to adjust common beliefs and coordinate collective action choices. The second proposition suggests that convergent perceptions are likely to inhibit collective action to adapt to climate change due to groupthink dynamics.

Our findings suggest that in general, community members will contribute to adapting to climate change at the community-level regardless of perception convergence. Importantly, our results suggest that groups with perception convergence are likely to systematically make significantly greater contributions to climate change adaptation than groups with non-convergent perceptions. These findings are robust to controlling for individual socio-economic characteristics, traditional ecological knowledge, and previous experience with the impacts of climate change. Our findings lend support to Proposition 1, which suggests that groups with convergent perceptions are more capable of coordinating actions at the group level in response to increased uncertainty. These findings run contrary to Proposition 2, as groups with convergent perceptions did not exhibit lower collective adaptive behaviour as the groupthink thesis suggests.

Remaining cognisant of the strengths and limitations of our experimental approach [34,52], our findings provide robust preliminary evidence on the role of perceptions and, specifically, how individual perceptions affect the collective. That we find a robust statistical association between perception convergence and climate change adaptation behaviour suggests that perception convergence is an important factor that can either drive or hinder adaptation efforts at the community level. Notwithstanding the tangible and intangible utility of traditional ecological knowledge and the general consensus that Indigenous communities are best placed to understand the impacts of climate change [9,11,84], we suggest that individuals within communities will likely hold different perceptions of climate anomalies due to shifting baseline syndrome [69] , change blindness [2,81] and memory illusions [18]. Our findings suggest that such a situation where perceptions are non-convergent may in turn inhibit the collective action required to adapt to climate change at the community level.

Given the experimental set-up of our study, our findings cannot be seen as conclusive. Instead, we recommend that our findings be viewed as the results of a scoping study through which we used a rigorous experimental protocol to probe for a systematic relationship between the convergence of perceptions of climate anomalies and climate change adaptation behaviour. That we found robust evidence of this relationship within our experimental parameters suggests that a greater understanding of perceptions and collective action dynamics is required to understand both how perceptions translate into the collective and the effect of convergent or non-convergent perceptions on community-level climate change adaptation behaviour. We suggest that a wide range of methodological approaches that use different methods of measuring perceptions of climate anomalies and observing and measuring climate change adaptation behaviour would help create a robust evidence base from which to build on our findings and better understand the relationship between perceptions of climate anomalies and climate change adaptation behaviour and the actual mechanisms through which perception convergence may affect behaviour [52,92].

6. Conclusions

We used an artefactual field experiment to explore the effect of individual perceptions of climate anomalies on collective climate change adaptation behaviour among six Indigenous communities in Malaysian Borneo. Controlling for other factors such as traditional ecological knowledge, we found that groups with convergent perceptions of climate anomalies significantly outperformed groups with non-convergent perceptions in terms of collective adaptation behaviour. Our findings suggest that the degree to which perceptions of climate anomalies converge in a given community may play a significant role in driving or inhibiting climate change adaptation behaviour at the community-level. Given the nature of climate change and the increased frequency and severity of climate anomalies, as well as widely documented mechanisms through which perceptions of climate anomalies may be affected at the individual-level, we suggest that many Indigenous communities are likely characterised by a significant degree of perception non-convergence that may be inhibiting their ability to adapt to climate change. The prevalence of consensus- and community-based decision-making practices in many Indigenous communities (e.g. [33,42]), however, may help them to overcome instances of perception non-convergence.

Declaration of Competing Interest

None.

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Supplementary materials

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