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RESEARCH ARTICLE

The benefits of citizen science and nature-noticing activities for well-being, nature connectedness and pro-nature conservation behaviours

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Abstract

1. The current biodiversity crisis, extinction of experience of nature and rising concern about people's well-being and mental health require us to understand the benefits of activities supporting people's engagement with nature.
2. We ran a 1-week randomised controlled experiment to test the impact of nature-focussed activities on people's connectedness to nature and well-being. This project, called 'Nature Up Close and Personal: A Wellbeing Experiment' recruited 500 people who completed the pre- and post-participation surveys which included seven psychometric outcome measures.
3. People were randomly assigned to one of six groups. Those in non-control groups were asked to take part in one 10-min activity five times over 8 days; this could be done in any place with nature near to them. The activities were as follows: two different citizen science activities, a nature-noticing activity (asking people to note three good things in nature: 3GTiN) or a combination of citizen science and 3GTiN.
4. Citizen science, 3GTiN and the combination of the two had significant positive effects on nature connectedness, happiness, sense of worthwhile life and satisfaction with life. 3GTiN (alone and in combination with citizen science) had significant positive effects on pro-nature conservation behaviours.
5. All activities engaged the pathways to nature connectedness. Compared to 3GTiN, people doing citizen science scored lower at engaging with nature through their senses, and feeling calm or joyful, but higher for feeling that they made a difference. The combined activity engaged the pathways to nature connectedness at least as strongly as the highest scoring of citizen science or 3GTiN individually. This shows the potential to intentionally design citizen science to enhance the pathways to nature connectedness.
6. Nature-based citizen science is more than just a way to gather environmental data: it benefits well-being and nature connectedness of participants, and (when

in combination with noticing nature activities) pro-nature conservation behaviours. It adds to the range of activities already proven to enhanced human–nature interactions and nature connectedness. Public policy needs to develop a 'one health' approach to people's engagement with nature, supporting communities to both notice and monitor everyday biodiversity, recognising that human and nature's well-being is interdependent.

KEYWORDS
behaviour, environmental monitoring, extinction of experience, human–nature interaction, nature connection, nature contact

1 | INTRODUCTION

Nature is declining in much of the world (IPBES, 2019), profoundly impacting people and all of the natural world (Cardinale et al., 2012). Nature contributes to people in many different ways, including ecosystem services such as pollination and pest control, as well as through 'non-material aspects of quality of life' such as people's health and well-being (IPBES, 2019). The continued decline in biodiversity indicates that the human–nature relationship is failing. Loss of wildlife in many people's environment is resulting in an 'extinction of experience' (Pyle, 2003; Soga & Gaston, 2016) and reduction in people's connection to nature (Richardson et al., 2020). A growing body of research has clearly demonstrated how important people's active engagement with nature is to their health and well-being (Dobson et al., 2021; Martin et al., 2020; Pritchard et al., 2020; Richardson et al., 2021; Soga & Gaston, 2021), and to individual behaviours that are beneficial for nature conservation and the environment (Mackay & Schmitt, 2019; Richardson et al., 2020).

The well-being effects of nature can be influenced by two factors: people's contact with nature and their connectedness to nature (Martin et al., 2020). These factors have alternately been described as opportunity, capability and motivation (Soga & Gaston, 2021). The benefits of contact with nature require opportunity to access biodiverse nature: health is positively associated with access to greenspace (de Vries et al., 2003; Maas et al., 2006), and well-being is positively associated with biodiversity richness (Cameron et al., 2020; Methorst et al., 2021). Although spending time in nature is positive for well-being (White et al., 2019), the length of time in nature or number of visits do not fully explain the strength of an individual's connection with nature (Martin et al., 2020; Richardson et al., 2021). Thus, benefits from nature contact may not depend upon a 'dose' related to time, but rather depend on how people engage with nature or one's connection with nature (Dobson et al., 2021; Passmore et al., 2022; Passmore & Holder, 2017; Richardson et al., 2020, 2021; Schuttler et al., 2018).

Connection with nature can be described by the measurable psychological construct of nature connectedness, that is, an individual's subjective sense of their relationship with nature (Martin et al., 2020; Mayer & Frantz, 2004). Lumber et al. (2017) provided a framework for which activities can be designed to enhance nature connectedness through the five pathways to nature connectedness. These pathways are as follows: contact, beauty, meaning, emotion and compassion. Activities that have been proven to enhance nature connectedness include even brief psychological interventions, such as using senses to notice and then record 'Three Good Things in Nature' (3GTiN; Richardson & Sheffield, 2017). Increased nature connectedness is important because it brings sustained and clinically significant benefits to mental health, with greatest benefits to those with lowest starting levels of nature connectedness (McEwan et al., 2019). Moreover, nature connectedness is a main driver of pro-environmental behaviour (Mackay & Schmitt, 2019), over and above time in nature (Richardson et al., 2020).

In addition to activities designed to support nature connectedness, a different way of engaging with nature is taking part in nature-based citizen science outside in the environment. Citizen science is the intentional involvement of volunteers in science and monitoring, often involving data collection while spending time in nature (Pocock et al., 2017). It is an increasingly valued route of data provision for scientific research and monitoring (Dickinson et al., 2012; McKinley et al., 2017), and it provides numerous benefits for participants including enhanced learning, empowerment in decision-making, social engagement, and engagement with the natural world (McKinley et al., 2017; Peter et al., 2021; Phillips et al., 2018). Nature-based citizen science potentially supports people's well-being over-and-above the benefits of being outside (Coventry et al., 2019; Schuttler et al., 2018) because it provides a purposeful activity to support nature contact and connection (observing, identifying, measuring or sampling). However, it is not clear that taking part in nature-based citizen science leads to increases in nature connectedness, or that it activates the pathways to nature connectedness (Schuttler et al., 2018). Indeed, it is possible that the requirements to follow a protocol and use technology to submit results could distract people from the pathways to nature connectedness and may even result in frustration, thus interfering with their ability to connect with nature. Furthermore, existing studies about the impacts of citizen science for people tend to focus on those who had already chosen to participate in citizen science (e.g. Peter et al., 2021), rather than using a controlled experimental design.

Our goal in this study was to assess the impact of different nature-based activities on well-being, nature connectedness and

pro-environmental behaviour. Specifically, we conducted a 1-week randomised controlled experiment utilising pre- and post-participation surveys of our dependent variables. Participants were randomly assigned to one of six conditions: (1, 2) one of two citizen science activities (a pollinator survey or butterfly recording); (3) the 3GTiN activity in which people intentionally notice and record 'three good things in nature'; (4, 5) a combination of 3GTiN and citizen science; or (6) a control condition. In summary, the hypotheses that we tested were as follows: (1) Participants would report significantly higher levels of our outcome measures of nature connectedness, health, well-being and pro-nature conservation behaviour in the nature-based activity groups compared to the control. Because 3GTiN has proven impact on nature connectedness (Richardson & Sheffield, 2017), whereas the citizen science activities were not designed for this purpose, we expected that (2) 3GTiN would have greater impact on our outcome measures than citizen science, and (3) 3GTiN would more strongly engage the pathways to nature connectedness than citizen science and would cause less frustration for participants. (4) The combined activity (CS and 3GTiN) would have greater impact on the reported outcomes than citizen science or 3GTiN alone because it would take on the positives of each.

2 | METHOD

2.1 | Design and recruitment

Our project was promoted as 'Nature Up Close and Personal: A Wellbeing Experiment'. People were invited to sign up to the project between 14 July 2020 and 26 August 2020 and (for those not in the control group) to participate five times in their randomly assigned activity over an 8-day period (Figure 1). The project was publicly promoted in the UK by the research project partners and the British Science Association. Press releases generated two articles in the national print media and 28 pieces of regional or trade coverage during the period of signups for the project. The project was widely circulated via social media (especially Twitter) with the hashtag '#CloseToNature'. During the recruitment period (14 July to 25 August 2020), social media posts were viewed widely. For example, a short 1-min Youtube video to promote the project (https://youtu.be/EW_Y99jYo4c) had 32,880 views across social media platforms.

Overall, 1295 people completed the consent form and the pre-participation survey (Appendix S1), and so were randomly assigned to one of six conditions (five experimental conditions or a control group;

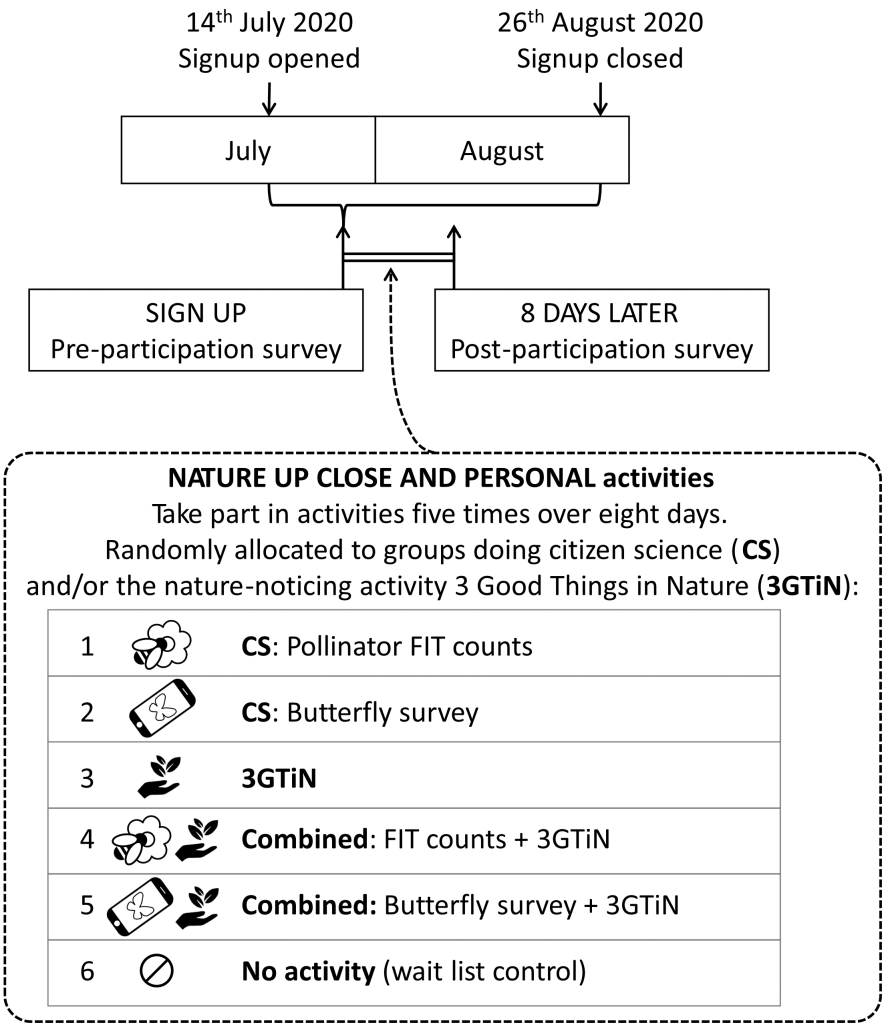

FIGURE 1 Chronology of the Nature Up Close and Personal project and the evaluation of impacts of activities via surveys on well-being and nature connectedness.

see below for details). Participants assigned to one of the experimental interventions were given a link to a webpage giving information about their assigned activity. All activities provided 10 min of nature contact each time someone took part; we decided on this timeframe so that all activities matched the existing time requirement for the pollinator flower-insect timed (FIT) counts citizen science activity. So as to provide a reasonable amount of nature contact time, but without being too onerous, participants were asked to engage in their 10-min activity at least five times (weather permitting) over the next 8 days (Figure 1). The citizen science activities required some preparation in advance (i.e. reading the instructions, marking out a sampling location, printing a reporting sheet and reading about how to identify the different insect groups). Participants were instructed to engage in their activity in a 'natural, green space local to them (e.g. a garden or yard, a park or the countryside)', so anyone was able to participate. All participants were given information on staying safe, abiding by local COVID-19 restrictions, and how to access independent support for mental health. Each participant in the experimental groups was sent a daily reminder email asking them to record whether they had completed the activity that day and, for the 3GTiN activity, to enter the three good things that they had noticed in nature that day. All participants were then debriefed and were provided with the instructions for all the activities so they could engage with these if they wanted to.

After 8 days, all participants (including those in the wait list control) were asked to complete the post-participation survey (Appendix S1) which included the same questions as the initial survey; participants were also asked to answer closed and open questions about their experience of participation and to provide their postcode district (e.g. 'OX10'). Our final sample consisted of 500 people (39% of those who signed up) who completed the post-participation survey and either took part in activities at least once (381 people) or were in the control group.

All participants provided informed consent, recorded via an online tick box labelled 'Yes—I accept' that followed a written brief on a 'Your Consent' page. The Psychology Research Ethics Committee at the University of Derby approved the study and consent procedure (ETH1920-3432). The study was administered using Qualtrics online survey software.

2.2 | Measures

We used a set of previously validated, commonly used scales in both the pre- and post-participation surveys to assess people's nature connectedness, health, well-being and engagement in pro-nature conservation behaviour. In the post-participation surveys, we also asked quantitative and qualitative questions about people's experience of taking part and the pathways to nature connectedness.

2.2.1 | Nature connectedness

We used two scales that emphasise different aspects of nature connectedness (Tam, 2013). First, the Inclusion of Nature in Self scale (INS: Schultz, 2001) asks participants to report the extent to which nature is included in their sense of self. Respondents select an image (two circles varying in their degree of overall) that best represents the relationship between their self and nature. Second, the Nature Relatedness scale (NR6: Nisbet & Zelenski, 2013) is a more multi-dimensional, 6-item measure of subjective nature connectedness, focussing on the affective, cognitive and experiential aspects. The NR6 demonstrates sound psychometric qualities in terms of internal consistency, temporal stability and validity. Items are rated on a 5-point scale from 1 'Disagree strongly' to 5 'Agree strongly'.

2.2.2 | Health and well-being

Physical health was measured using a single-item scale ranging from 1 'Poor' to 5 'Excellent'. This scale has been found to perform as well as multi-item measures of self-reported health in both cross-sectional and longitudinal research (Macias et al., 2015).

Several aspects of well-being were assessed. The Happiness Index (Abdel-Khalek, 2006) was utilised wherein participants respond to the question 'Do you feel happy in general?' using an 11-point scale with endpoints ranging from 0 = 'Not at all happy' to 10 = 'Very happy'. Life satisfaction and sense of worthwhile life were measured using two items from the Office for National Statistics subjective well-being survey questions (Hicks et al., 2013). Both items were rated on 11-point scales ranging from 0 'Not satisfied at all'/'Not at all worthwhile' to 10 'Completely satisfied'/'Completely worthwhile'.

2.2.3 | Pro-conservation behaviour

Pro-nature conservation behaviours were measured using the short-form Pro-nature conservation Behaviour Scale (Barbett et al., 2020). Participants indicate how often they perform eight specific pro-nature conservation behaviours (e.g. picking up litter, being politically involved with conservation issues or doing wildlife-friendly gardening) using a 7-point scale from 1 = 'Never' to 7 = 'Always'.

2.2.4 | Self-reported experience and pathways to nature connectedness

Post-participation, we asked people about their responses to taking part in the activities. Participants indicated responses to six questions with a 5-point scale from 1 'Completely disagree' to 5 'Completely agree'. Five questions were informed by the pathways to nature connectedness (Lumber et al., 2017): (i) I felt close to nature through my senses while taking part; (ii) I found taking part calming or joyful; (iii) I noticed nature's beauty while taking part; (iv) I found taking part meaningful and (v) I felt I was helping take care of nature by taking part. We thought that citizen science activities may evoke frustration as they usually require adherence to a protocol,

require submitting results using technology and do not emphasise emotional experiences of enjoyment of nature. To capture this possibility, our sixth question was: (vi) I found taking part frustrating.

2.2.5 | Levels of engagement

Participants in the experimental groups were also asked three questions about their level of engagement in their randomly assigned activity: (i) the number of times they took part in their assigned activities; (ii) their engagement with the task (rated on a 4-point scale from 'not engaged at all' to 'very engaged') and (iii) the amount of time they spent outdoors (rated on a 5-point scale from 'none at all' to 'a great deal').

2.2.6 | Open-ended questions

Post-participation, participants in the experimental groups were also asked to give a free-text response to the open questions 'What did you like about taking part?' and 'What didn't you like about taking part'. The answers to these questions provided contextual information about their participation, in addition to the closed questions described above, that was suitable for coding to test our hypotheses.

2.3 | The experimental groups

2.3.1 | Group 1. Citizen science: Pollinator FIT (flower-insect timed) counts ($N = 43$)

Pollinator FIT counts is a semi-structured citizen science activity (i.e. people follow a protocol, but where and when they choose) that is part of the UK Pollinator Monitoring Scheme (https://ukpoms.org.uk/) and gathers data for monitoring pollinators in Great Britain. Comprehensive instructions and user guides were available on the project website. Participants were instructed to choose a time when the weather was warm, not too windy and (preferably) sunny, to spend 10 min counting insects visiting a patch of flowers (a 50 × 50 cm patch of one type of flower), and to submit the records on the project webpage. Instructions were provided to identify insects into the following groups: bumblebees; honey bees; solitary bees; wasps; hoverflies; other flies; butterflies and moths; beetles larger than 3 mm; and small insects (less than 3 mm long). Participants could repeat the activity in the same place each day or choose different places.

2.3.2 | Group 2: Citizen science: Butterfly surveys ($N = 94$)

Participants in the second group were asked to choose a time when the weather was warm, dry, not too windy and (preferably) sunny and to spend 10 min looking for butterflies, either in a single location or during a walk. They were invited to use the iRecord Butterflies app (https://www.brc.ac.uk/article/irecord-butterflies-mobile-app; free to download for Android and Apple devices) to identify butterflies and submit their counts, or to submit records via a website (https://www.brc.ac.uk/irecord/). The app was designed to support general butterfly recording by naturalists, rather than specifically designed for timed counts. Verified records are used in ecological research (Pocock et al., 2015).

2.3.3 | Group 3: Three Good Things in Nature (3GTiN) activity ($N = 108$)

Those in the third group were asked to spend 10 min in a natural green space ('anywhere with some nature'), to look and listen to the natural world around them and to write down three good things they had noticed in nature. These could be the beauty of small things at any one moment, or the diversity and wonder of the natural world around them. This was based on the Three Good Things in Nature (3GTiN) intervention developed by Richardson and Sheffield (2017), which has demonstrable, sustained impact on people's nature connectedness and well-being (McEwan et al., 2019). The instructions suggested that people could list their emotion as something good they noticed in nature, because recording emotions evoked by nature encountered on a daily basis has been demonstrated to significantly boost well-being (Passmore et al., 2022; Passmore & Holder, 2017).

2.3.4 | Groups 4 and 5: Citizen science combined with the 3GTiN activity ($N = 52$ and 84 for FIT counts and Butterfly survey, respectively)

For the fourth and fifth groups, participants had the same instructions as the two citizen science projects but we asked that, while undertaking the counts and 'when the opportunity arises, and so as not to interfere with the citizen science', they also do the 3GTiN activity, as described above.

2.3.5 | Group 6: Wait list control ($N = 119$)

Participants in this group were informed, after they had completed the pre-participation survey, that they would be contacted again in 8 days. At that time, they were asked to completed the post-participation survey and when they had completed it they were given information on the citizen science and 3GTiN activities given to the other groups. This is the so-called wait list control, as are commonly used in randomised control experimental intervention studies (e.g. Passmore & Holder, 2017).

2.4 | Analysis

2.4.1 | Participant demographics and levels of participation

First, we tested for differences between the 500 participants and those who dropped out of the study. We used ANOVA to test for differences in initial levels of nature connectedness between the participants and those who dropped out. We used χ^2 to test for differences in the dropout rates across the six groups and used post-hoc χ^2 tests with Bonferroni correction to identify significant differences between groups (Beasley & Schumacker, 1995). To consider whether the participants were different from the general population in terms of their socio-economic status, we used the Index of Multiple Deprivation (Parsons, 2021) to compare the locations of participants with the whole country (for details, see Appendix S2).

Second, we tested for differences in participants across the groups in the study. ANOVA was used to test for differences in the initial levels of nature connectedness across the six groups. For those in the five experimental conditions, we then used χ^2 to test for differences in the proportion of people who took part at least five times, and used ANOVA to test for differences in their level of engagement and the amount of time they spent outside.

Here, and elsewhere in this study, we used ANOVA and ANCOVA (controlling for pre-intervention scores) because these tests are robust to deviations from normality (Schmider et al., 2010). Post-hoc tests were conducted using Fisher's least significant difference (LSD) tests.

2.4.2 | Analysis of measures

Given that our hypotheses focussed on comparing the effect of engaging with nature via CS to engaging with nature via a noticing nature activity (the 3GTiN activity), we first ran ANCOVAs (using pre-scores as covariates) to determine whether the two CS groups differed significantly on any of the outcome measures (i.e. the measures of nature connectedness, well-being, health and pro-nature conservation behaviour). We confirmed that the two CS activities (Pollinator FIT Counts and Butterfly Surveys) did not significantly differ on any of the outcome measures (INS: $F_{1,134} = 0.478$, $p = 0.491$, $\eta^2_p = 0.004$; NR6: $F_{1,134} = 0.382$, $p = 0.538$, $\eta^2_p = 0.003$; Satisfaction with life: $F_{1,126} = 0.644$, $p = 0.424$, $\eta^2_p = 0.006$; Sense of worthwhile life: $F_{1,134} = 0.841$, $p = 0.361$, $\eta^2_p = 0.006$; Health: $F_{1,134} = 0.049$, $p = 0.824$, $\eta^2_p = 0.000$; Happiness: $F_{1,134} = 0.970$, $p = 0.326$, $\eta^2_p = 0.007$; Pro-nature conservation behaviour: $F_{1,122} = 0.478$, $p = 0.491$, $\eta^2_p = 0.004$). Based on this finding, we grouped the CS activities together leaving four groups for the main analysis: CS ($N = 137$), 3GTiN ($N = 108$), Combined ($N = 136$) and Control ($N = 119$).

To test that the experimental groups differed in their effect on nature connectedness, health, well-being and pro-nature conservation behaviour, we ran an ANCOVA for each outcome measure, using the relevant pre-participation score as a covariate When the ANCOVA was significant, we conducted post-hoc pairwise LSD tests to compare post-survey measures between the four groups to test our first hypothesis (nature-based activities were different to the control) and second hypothesis (3GTiN has greater impact than citizen science). Within-group paired *t*-tests of the change in scores were conducted to show the overall impact of the experimental groups on the change in scores between the pre- and post-participation surveys. As a supplementary analysis, we used multiple regression analyses for each of the seven outcome measures to test for the effect of personal attributes (age, gender, latitude, IMD, baseline nature relatedness and number of times activities were undertaken) on the difference in outcome measure score between the pre- and post-participation survey (Appendix S3).

To test our third hypothesis (that 3GTiN would more strongly engage the pathways to nature and cause less frustration than CS or Combined), a series of one-way ANOVAs was performed on the scores of participants' experience. Where the ANOVA was significant, post-hoc pairwise LSD tests identified which of the experimental interventions differed from each other.

2.4.3 | Methods for qualitative analysis

For open responses, we used content analysis to code the responses into themes; the themes were determined primarily by the data but previous studies (Peter et al., 2021; Tiago et al., 2017) were used to help inform the themes. Two authors independently coded one-quarter of the responses to each question and through discussion they refined the definition of the themes raised by the participants. Responses were divided into statements, each addressing one theme. Both authors then independently coded each statement. Inter-rater reliability was high: Cohen's $k = 0.84$ and 0.88 for answers to the positive and negative questions, respectively. Subsequently, one author coded all remaining responses.

To analyse the coded open responses, we undertook χ^2 tests to test for variation in the prevalence of themes across all six experimental groups (i.e. treating the two citizen science activities separately), and used post-hoc χ^2 tests with Bonferroni correction to identify significant differences between groups.

3 | RESULTS

3.1 | Participation and participant demographics

Of the 1295 people who completed the pre-participation survey and were allocated to groups, 500 people (the 'participants') completed the full requirements for the study (i.e. completing the post-survey measures and either taking part in their assigned activities at least once or being allocated to the wait list control). The rate of dropout varied across conditions (Figure 2a; $\chi^2_5 = 90.012$; $p < 0.001$). Post-hoc χ^2 tests showed that this was explained by the significantly higher dropout rate (76%–80%) for groups with the pollinator FIT

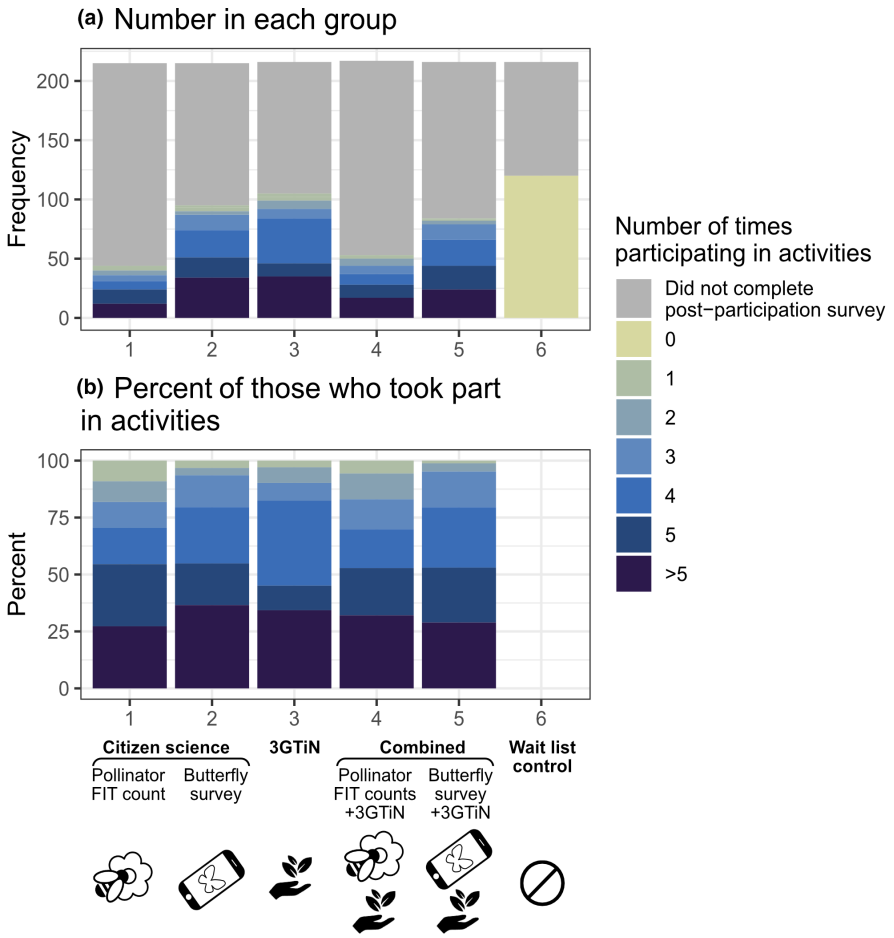

FIGURE 2 Rates of participation in the Nature Up Close and Personal project. (a) Equal numbers of people were allocated to each group, but (a) the number of people who completed the post-participation survey and (b) the number of times that people reported participating in activities also varied across groups.

counts and lower dropout rate for the 3GTiN and wait list control groups (45%–50%).

For the participants, age was approximately normally distributed (mean = 51.59 years, SD = 14.21), but gender was strongly female-biased (81% females, 17% males, 0.4% non-binary, 1.0% did not specify). Most participants self-identified as white (93.6%), with smaller numbers identifying as other ethnic groups (2.0% mixed, 1.0% Asian, 0.8% other, 2.6% preferred not to give details). The 500 participants had higher INS measures, but no difference in NR6, compared to those who dropped out (INS: participants mean = 4.7, dropped out mean = 4.4; $F_{1,1285} = 15.819$, $p < 0.001$; NR6: participants mean = 4.2, dropped out mean = 4.2; $F_{1,1292} = 0.694$, $p = 0.405$), indicating there may have been some selection bias for those who completed the study. Participants were from across the UK, but from more affluent areas than average (Kolmogorov–Smirnoff test: $D = 0.112$, $p < 0.001$; Appendix S2).

Despite the variation in dropout rates, there was no significant variation in the initial nature connectedness levels of participants between the six groups (INS: $F_{5,494} = 0.794$, $p = 0.555$; NR6: $F_{5,494} = 1.186$, $p = 0.315$). Over half of the participants took part in activities at least five times (59%) as we requested. There was significant variation across groups for those taking part at least five times (Figure 2b; $\chi^2_4 = 12.229$; $p = 0.016$; post-hoc χ^2 tests showed 3GTiN was significantly higher than other groups) but not for those taking part at least four times ($\chi^2_4 = 2.778$; $p = 0.596$). Participants' level of engagement and time spent outdoors did not vary significantly between the five groups (level of engagement: $F_{4,376} = 0.912$, $p = 0.457$; time spent outdoors: $F_{4,376} = 1.654$, $p = 0.160$) and other demographic characteristics were similar between the groups (Table S1).

3.2 | Effects of the activities on the outcomes

We found that our first hypothesis was confirmed: people taking part in nature-based activities (CS, 3GTiN and Combined) increased in nature connectedness, well-being and pro-nature conservation behaviour scores during the study, while those in the wait list control group showed no change. Specifically, we found significant differences across the four groups for INS, NR6, sense of worthwhile life and happiness (Table 1). The post-hoc analyses reveal that all three nature-based activities reported higher well-being and nature relatedness than the control group, although there were no significant differences between 3GTiN, CS and Combined, so our second and fourth hypotheses (that 3GTiN had a greater impact than CS, and that Combined was greater than both) were not supported (Table 1). There was no significant change from pre- to post-intervention in the control group, whereas scores for the nature-based activities groups increased (Table 2). The outcome measure of health showed no difference across groups, but this was expected because the intervention

TABLE 1 Differences in the effect on outcome measures between the four groups (CS: citizen science; 3GTiN: three good things in nature activity; Combined: CS with 3GTiN; or the wait list Control). The results are from ANCOVA analysis of scores from post-participation surveys, taking account of their values in the pre-participation surveys.

Outcome measure	*F*	Significance (*p*)	η^2_p	Pairwise post-hoc differences between the four groups	Mean difference	Significance (*p*)
Inclusion of nature in self (INS)	10.71	<0.001	0.061	CS—Control	0.364	<0.001
				3GTiN—Control	0.549	<0.001
				Combined—Control	0.458	<0.001
				CS—3GTiN	−0.184	0.073
				CS—Combined	−0.094	0.333
				3GTiN—Combined	0.091	0.378
Nature Relatedness Scale (NR6)	4.96	0.002	0.029	CS—Control	0.12	0.004
				3GTiN—Control	0.13	0.003
				Combined—Control	0.15	<0.001
				CS—3GTiN	−0.01	0.804
				CS—Combined	−0.02	0.576
				3GTiN—Combined	−0.01	0.782
Satisfied with life	2.60	0.052	0.016	CS—Control	0.26	0.043
				3GTiN—Control	0.33	0.014
				Combined—Control	0.29	0.022
				CS—3GTiN	−0.07	0.571
				CS—Combined	0.03	0.783
				3GTiN—Combined	0.04	0.758
Sense of worthwhile life	3.57	0.014	0.021	CS—Control	0.29	0.027
				3GTiN—Control	0.31	0.027
				Combined—Control	0.41	0.002
				CS—3GTiN	0.02	0.895
				CS—Combined	−0.12	0.339
				3GTiN—Combined	−0.10	0.444
Health	0.30	0.828	0.002	n/a[a]		
Happiness	3.61	0.013	0.021	CS—Control	0.31	0.018
				3GTiN—Control	0.35	0.010
				Combined—Control	0.39	0.003
				CS—3GTiN	−0.05	0.726
				CS—Combined	−0.08	0.525
				3GTiN—Combined	0.03	0.805
Pro-nature conservation behaviour scale	2.23	0.084	0.015	CS—Control	1.01	0.072
				3GTiN—Control	1.34	0.023
				Combined—Control	1.25	0.027
				CS—3GTiN	−0.33	0.555
				CS—Combined	−0.24	0.649
				3GTiN—Combined	0.09	0.878

[a]Only shown where the main ANCOVA was significant ($p < 0.05$) or $p < 0.084$.

was so short term. There were no clear additional effects of most personal attributes, such as age, location or level of engagement on the change in the outcome measures, except that people taking part more frequently were likely to show a stronger change in pro-nature conservation behaviours and females showed a stronger increase in happiness and satisfaction with life (Appendix S3).

We found mixed evidence for our third hypothesis that 3GTiN would more strongly engage the pathways to nature connectedness than CS. People in the three intervention groups (CS, 3GTiN and Combined) differed in their responses on four of the five pathways to nature connectedness (Figure 3a–e). Post-hoc tests revealed that people in the CS group felt less close to nature through their senses, and found taking

TABLE 2 Means (and SDs) for the scores from pre- and post-participation surveys by group and outcome measure showing the direction of the change, with paired t-tests indicating the significance of changes over time.

	Citizen science (CS)			Three good things in nature (3GTiN)			Combined (CS + 3GTiN)			Wait list control		
	Pre	Post	*t* value (*p*)	Pre	Post	*t* value (*p*)	Pre	Post	*t* value (*p*)	Pre	Post	*t* value (*p*)
Inclusion of nature in self scale (INS)	4.54 (1.36)	4.85 (1.18)	+2.77 (**0.006***)	4.47 (1.39)	5.01 (1.20)	+3.87 (<**0.001***)	4.51 (1.39)	5.07 (1.18)	+2.97 (**0.004***)	4.42 (1.37)	4.42 (1.30)	−1.73 (0.086)
Nature relatedness scale (NR6)	4.24 (0.65)	4.37 (0.55)	+2.76 (**0.007***)	4.16 (0.69)	4.30 (0.58)	+4.14 (<**0.001***)	4.25 (0.62)	4.44 (0.52)	+4.03 (<**0.001***)	4.18 (0.62)	4.20 (0.64)	+0.12 (0.905)
Satisfied with life	6.47 (1.81)	6.96 (1.80)	+4.08 (<**0.001***)	6.42 (1.83)	6.94 (1.78)	+4.57 (<**0.001***)	6.47 (1.78)	7.17 (1.50)	+4.07 (<**0.001***)	6.45 (1.77)	6.68 (1.55)	+1.76 (0.082)
Sense of worthwhile life	6.86 (1.72)	7.32 (1.71)	+3.10 (**0.002***)	6.73 (1.83)	7.17 (1.72)	+3.49 (<**0.001***)	6.91 (1.75)	7.51 (1.58)	+4.57 (<**0.001***)	6.62 (1.98)	6.71 (1.80)	+1.28 (0.204)
Health	3.44 (0.94)	3.54 (0.98)	+1.55 (0.123)	3.31 (0.95)	3.40 (1.10)	+1.73 (0.086)	3.27 (0.97)	3.39 (1.02)	+2.92 (0.004)	3.37 0.98)	3.53 (1.00)	+0.96 (0.338)
Happiness	6.84 (1.90)	7.24 (1.82)	+3.87 (<**0.001***)	6.71 (1.84)	7.17 (1.96)	+4.63 (<**0.001***)	6.72 (1.81)	7.33 (1.68)	+4.39 (<**0.001***)	6.72 (1.89)	6.87 (1.74)	+0.84 (0.404)
Pro-nature conservation behaviour Scale	37.12 (9.40)	39.14 (8.45)	+1.61 **(0.109)**	35.92 (9.33)	36.9 8 (9.09)	+3.49 (<**0.001***)	36.27 (9.28)	38.87 (8.60)	+2.41 (**0.017**)	36.51 (9.79)	37.76 (8.68)	−0.76 (0.450)

Note: Significant effects ($p < 0.05$) are shown in bold; significance with sequential Bonferroni correction (one-tailed) at alpha = 0.05 are denoted by *.

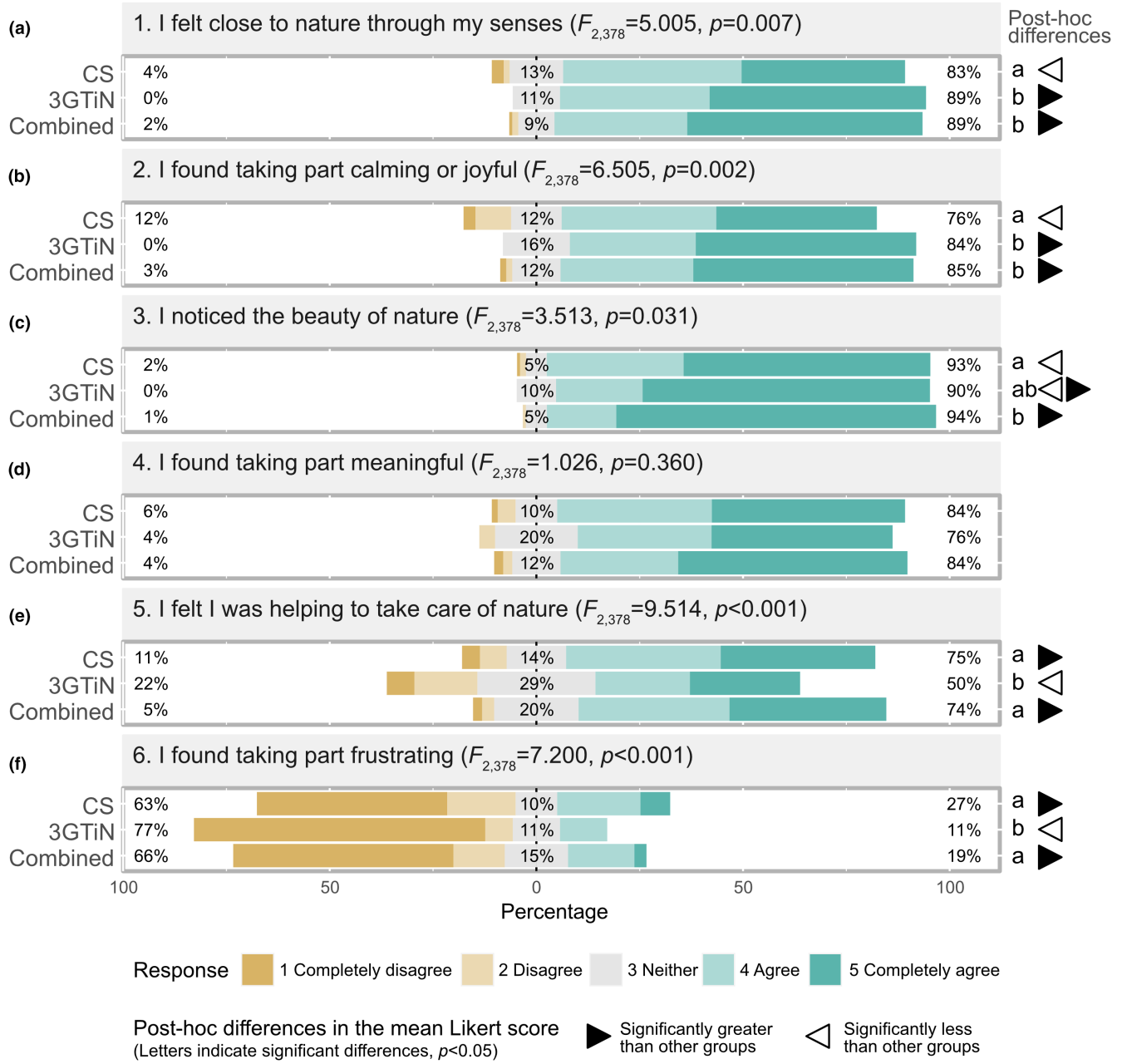

FIGURE 3 Differences in participant's experiences related to the pathways to nature connectedness, considering (a) contact, (b) emotion, (c) beauty, (d) meaning and (e) compassion, or to the negative emotion of frustration (f) between the citizen science (CS), Three Good Things in Nature (3GTiN) and combined conditions. For significant differences in the mean Likert score identified with an ANOVA, the filled arrows pointing right and the open arrows pointing left indicate conditions that were significantly higher or lower, respectively, from each other with pairwise post-hoc tests.

part less calming or joyful than those in the 3GTiN or Combined group; those in the CS group also noticed the beauty in nature less than those in the Combined group. Conversely, those in the CS and Combined groups felt more strongly that they were helping to take care of nature than those who did the 3GTiN activity. There was no difference between the three groups in finding that taking part was meaningful. Although the Combined activity did not have greater impact than citizen science or 3GTiN alone (our fourth hypothesis) its impact on each of the pathways to nature connectedness was at least as good as (i.e. never significantly worse than) the best of CS and 3GTiN individually. Taking part could also have elicited negative emotions, and we found significant differences in people's level of frustration which, as we expected, was driven by those doing activities with a citizen science component (the CS and Combined groups) reporting higher frustration (Figure 3f).

3.3 | Qualitative analysis

Most of the participants in the experimental groups who responded to the post-participation survey also provided responses to the open

questions (77%). The responses were varied (Figure S2), and so the content analysis provided insight into possible reasons why the activities had beneficial effects on outcome measures, provided positive experiences, or were found to be frustrating (Table 3). Respondents stated that they most liked noticing nature around them (33%–56% of respondents, depending on the group) or gained intrinsic benefits through participation, such as having a break outdoors (26%–61%). Those who took part in the 3GTiN activity were particularly likely to describe these intrinsic benefits. Fewer people, but from across all groups, said that they liked contributing to something important (9%–13%), while only those who did citizen science said that they learned through the activity (13%–23%, compared to 0% of 3GTiN participants).

The range of responses about what people did not like about participating was more diverse (Table 3). Weather was a major limitation, especially for those doing butterfly surveys (31%), but it was raised as an issue less for those doing 3GTiN (8%) which could be done whatever the weather. About one-fifth of people (17%–23%) said that they felt they lacked time, kept forgetting or did not like the feeling of being obligated to do the activities. The flexibility of the 3GTiN activity appeared to be beneficial because fewer people doing this complained about the weather or the lack of success in the task. Those doing pollinator FIT counts were more likely to say that they did not like the complexity of the task (13%–27%, compared to 1%–6% for the other groups), whereas those doing butterfly surveys with the smartphone app said that they had technological problems (28%, compared to 0%–9% for the other groups; even though the smartphone app is well established and has been used by others for recording butterflies since 2014; August et al., 2020). Although only a few people stated that the formality of taking part interfered with their engagement with nature (3%–10%), this is nonetheless a valuable finding.

4 | DISCUSSION

4.1 | The benefit of nature-based activities

In the light of the inter-relationships of the current biodiversity crisis, people's reduced experience of nature and rising concern about mental health, it is important to understand the benefits of engaging with nature (Martin et al., 2020; Richardson et al., 2020; Soga et al., 2021; Soga & Gaston, 2016, 2021). In a randomised controlled experiment with 500 participants, we found that those participating in nature-based activities (the 3GTiN nature-noticing activity or citizen science) reported higher levels of measures of well-being and nature connectedness than those in the control group (supporting our first hypothesis; Table 1). The 3GTiN activity had no significantly greater impact on the outcome measures than citizen science (contrary to our second hypothesis; Table 1), although it did support stronger engagement with the pathways to nature connectedness than citizen science (supporting our third hypothesis; Figure 3), as it was designed to do (Lumber et al., 2017; Richardson & Sheffield, 2017). In contrast, the result for citizen science is valuable because it demonstrates its added value for participants, in addition to its purpose to gather scientifically rigorous environmental data from volunteers, and supports results of a smaller study by Coventry et al. (2019). Our findings were striking because all the interventions were relatively small scale (i.e. only providing 10-min doses of nature contact for up to five times across the 1-week study). To address people's reduced experience of nature, there needs to be a range of activities that can develop the human–nature relationship, and so the finding that citizen science approaches can increase nature connectedness is particularly valuable.

One benefit of developing people's experience of nature is the opportunity for reciprocal benefits for nature through pro-environmental action. We found that the 3GTiN and Combined activities led to increases pro-nature conservation behaviour scores (Table 1), and this effect was stronger the more frequently people took part in activities (Appendix S3). This suggests that engaging in nature-noticing or citizen science can ultimately lead to action for improvements in the natural world and supports previous studies, both correlative (Mackay & Schmitt, 2019; Richardson et al., 2020) and experimental (Wyles et al., 2017).

Contact, emotion, meaning, compassion and beauty are pathways to nature connection (Lumber et al., 2017), and the majority of people taking part in our activities (3GTiN, CS and Combined) reported that the activities positively engaged these pathways (Figure 3a–e). There were differences in these effects between the different groups: 3GTiN was more effective in supporting connections to nature through contact, emotion and beauty, whereas citizen science was more effective at supporting connections through compassion (even though 3GTiN had greater impact on pro-nature conservation behaviour scores). Engaging the pathways is important; activities that do not do this, for example, some environmental education or adventure activities, may not deliver sustained increases in nature connectedness (Bruni et al., 2017; Ernst & Theimer, 2011). In addition, the link between the pathways to nature connectedness and our outcome measures provide further validation of the pathways framework for activity design (Lumber et al., 2017).

Most people did not feel frustration while taking part, but frustration scores were higher for those doing activities involving citizen science (CS and Combined). The qualitative results (Table 3) indicate why this was the case: citizen science tasks were impacted by the weather, task complexity, technological challenges or lack of success, for example, not seeing any insects, although the two citizen science activities differed in their specific criticisms. In contrast, participants commented the 3GTiN activity was simple and flexible, which might also explain why those allocated to the 3GTiN group were more likely to complete the post-participation survey (Figure 2). However, some people doing the 3GTiN activity commented that it seemed artificial and interfered with their appreciation of nature.

Overall, the results show that individuals differ and there can be no 'one size fits all' solution for developing human–nature

TABLE 3 Percentage of responses assigned to each category in response to what people did and did not like about taking part in their assigned activity for the five experimental groups of citizen science (CS), Three Good Things in Nature (3GTiN) and the combined conditions

Category	Example quote	*N*	CS: Pollinator FIT counts	CS: Butterfly surveys	3GTiN	Combined: Pollinator FIT counts +3GTiN	Combined: Butterfly surveys +3GTiN	χ^2 (*p*)
Number of responses			39	90	99	52	82	
'What did you like?'								
Noticing nature	'It made me more aware of nature in all aspects of the environment'; 'Observing pollinators in great detail rather than a passing glance'	160	54%	46%	33%	56%	44%	9.103 (0.058)
Intrinsic benefits (including enjoyment of being outside)	'It reminded me that small things can make a big difference to my mood'; 'It gave me permission to slow down'; 'I was more aware of other senses (hearing, smell, touch) than normal (usually mostly sight and hearing)'	145	33%	**26%**[a] ↓	**61%**[a] ↑	37%	37%	26.71 (<0.001)
Contributing	'Knowing our information counts towards something is great'	38	10%	10%	11%	13%	9%	0.888 (0.926)
Learning	'Learning how to identify different butterflies'; 'I enjoyed learning more about pollinators'	48	15%	**23%**[a] ↑	**0%**[a] ↓	13%	17%	24.266 (<0.001)
Social connection	'I felt part of a wider community'	12	0%	3%	2%	4%	6%	3.882 (0.422)
Other[b]		8	5%	2%	1%	2%	2%	–
'What did you not like'								
Limitation of weather	'Weather at the time made it hard to feel like I could fully participate'	72	23%	**31%**[a] ↑	**8%**[a] ↓	17%	22%	16.46 (0.002)
Lack of time (including forgetting and feeling obligated)	'The exercise highlighted the difficulties of my week, my lack of time to do the things I love'; 'I found… trying to fit five days' observations into a week, a bit stressful'	77	23%	17%	22%	19%	17%	1.56 (0.816)
Task complexity	'I wasn't always confident about my butterfly identification!'	31	13%	**1%**[a] ↓	6%	**27%**[a] ↑	6%	31.10 (<0.001)
Technological problems	'Found the app a little difficult to find my way around'	36	0%	**28%**[a] ↑	**0%**[a] ↓	8%	9%	46.39 (<0.001)
Lack of success in task	'I could not spot any butterflies even though I tried on several occasions which was a little disheartening'.	46	13%	**21%**[a] ↑	**3%**[a] ↓	15%	13%	14.46 (0.006)

relationships—we need a menu of activities. Some people have an existing appreciation of nature but many do not notice nature around them (National Trust, 2020) and so may need prompts to notice nature (Soga et al., 2021). The task-based focus of both activities—either following a citizen science protocol, or writing three good things about nature—appeared to help many people to engage more with nature. The benefits from 3GTiN in previous work (McEwan et al., 2019; Richardson & Sheffield, 2017) were sustained and most strongly demonstrated for those with lower levels of nature connectedness. Further research on the sustained benefits of citizen science especially for those with lower nature connectedness would be valuable.

TABLE 3 (Continued)

Category	Example quote	N	CS: Pollinator FIT counts	CS: Butterfly surveys	3GTiN	Combined: Pollinator FIT counts +3GTiN	Combined: Butterfly surveys +3GTiN	χ^2 (p)
Interfered with nature engagement	'When I'm out in nature I like to not have my phone out'; 'I did not like the highly structured nature of the activity I was given ... preferred to engage with nature in a more informal way'	26	5%	3%	10%	8%	9%	3.76 (0.440)
Nothing to dislike		86	31%	16%	**37%**[a] ↑	12%	21%	19.23 (<0.001)
Other[b]		29	5%	8%	7%	10%	10%	–

[a]Post hoc χ^2 tests with Bonferroni correction indicated a significant difference from the expected value, being higher (↑) or lower (↓) than expected.
[b]The 'other' category was not analysed because it represented a mix of reasons.

4.1.1 | The benefits of citizen science for participants

Previous studies found that there are diverse reasons why people get involved with citizen science, for example, to support science and conservation or to take part with others (Larson et al., 2020; Pateman et al., 2021; West & Pateman, 2016), as well as for their own enjoyment (Tiago et al., 2017). Although our study was only a short-term intervention, the impacts of citizen science on well-being and nature connectedness are likely to contribute to changing motivations over long-term participation in citizen science (Larson et al., 2020; Rotman et al., 2012; West & Pateman, 2016). More generally, evidence from the current study can be used to highlight the well-being benefits of nature engagement, and specifically could be used to promote nature-based citizen science to those who have not previously engaged with it.

4.1.2 | The benefits of combining citizen science with the nature-noticing activity

Given the individual benefits of 3GTiN and CS, combining the two could be particularly beneficial (our fourth hypothesis). We did not find evidence that the combined activity was more impactful on the outcome measures than citizen science or 3GTiN alone (Table 1). However, while 3GTiN and CS varied in their impacts on the pathways to nature connectedness, the Combined activity seemed to gain from the best of 3GTiN and CS because it was not significantly less than the best of either of them for any of the pathways (Figure 3): it connected people to nature through contact, emotion and beauty (to the same extent as 3GTiN), and also through compassion (to the same extent as CS; Figure 3). This finding was all the more striking because our combination of the two activities was quite rudimentary: we simply directed people to notice good things in nature when it was convenient to do so during the citizen science activity. Better design could bring even greater benefits, so we recommend that project organisers intentionally design their citizen science project to enhance the pathways to nature connectedness, as well as to deliver high-quality environmental data.

4.1.3 | Potential limitations of this study

Despite the strengths of this study, several limitations could have influenced the results. First, the open public call for volunteers may have led to biases in participation, attracting people already highly connected to nature (and so possibly less sensitive to the benefits of further engagement with nature) or those most interested in improving well-being (so possibly being more sensitive to interventions). The sample was gender-biased, with a high representation of females (81%), although this appears to be somewhat typical of nature engagement campaigns (e.g. Hamann & Ivtzan, 2016; Richardson et al., 2016) and participants tended to come from areas that were more affluent than average (Appendix S2). There could also have been anticipation bias, such that people allocated to activities expected to gain benefits. While it is possible this could have affected comparisons of the control to the experimental interventions, it should not have affected comparisons between the experimental interventions.

Second, there was evidence of bias in the dropout rates. Specifically, those who dropped out had lower initial nature connectedness (for one of the two measures) than those who remained, and attrition was highest for the most complex citizen science activity, that is, the pollinator FIT counts (Figure 2), both of which are important findings about retention in nature-based activities. However, of the 500 people who did take part in activities, there was no significant difference across groups in their initial nature connectedness. Also other demographic characteristics were similar across the groups, thus indicating that any bias was not substantial.

Third, this study took place during early stages of the ongoing COVID-19 pandemic in the UK, a period when people had particularly positive attitudes towards nature (Natural England, 2020). This may have positively affected people's willingness to opt in to do nature-based activities. Also, during our study, strict restrictions on movement and socialising were being relaxed, likely leading to overall positive societal changes in well-being, although we do not expect this affected the overall comparison between our treatments.

Fourth, this was a short-term (1 week) intervention, and the impacts were evaluated shortly after participation. As such, findings of this study do not inform about the effect of continual participation in nature-based activities, for example long-term participation in citizen science. It is important to establish sustained benefits of interventions, so replication studies with follow-up assessments are needed.

5 | CONCLUSION

The biodiversity crisis demands a new relationship with nature: a future where people understand the importance of biodiversity, are engaged with data on the local state of their environment, and celebrate the simple joys in nature. Citizen science and noticing good things in nature present two quite different approaches to intentional engagement with the natural world yet, as we showed here, both can support improvements to well-being and a closer relationship with nature, thus contributing to a varied menu of nature engagement activities. Citizen science could be made even more beneficial for participants by explicitly bringing nature noticing approaches (more emotional and sensory engagement with nature) into its design. To help develop a culture of connecting with nature, public policy needs to develop a 'one health' perspective, supporting communities to both notice and monitor everyday biodiversity, recognising that human and nature's well-being is interdependent.

AUTHOR CONTRIBUTIONS

Michael Pocock, Miles Richardson and Iain Hamlin conceptualised the study; all authors designed the study; Jennifer Christelow, Holli-Anne Passmore and Michael Pocock ran the survey; Michael Pocock, Iain Hamlin and Miles Richardson analysed the data and, with Holli-Anne Passmore, led the writing of the manuscript. All authors reviewed and revised the manuscript and gave final approval for publication.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

An anonymised version of the data from this study is available on the Natural Environment Research Council's Environmental Information Data Centre (https://doi.org/10.5285/56d4b055-c66b-42b9-8962-a47dfcf3b8b0; Pocock et al., 2022).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix S1. Questionnaires used for the pre- and post-participation surveys.

Appendix S2. Distribution of participants according to the Index of Multiple Deprivation, including Figure S1.

Table S1. Characteristics of participants in the different experimental groups.

Appendix S3. Regression analysis of the effect of personal attributes on outcome measures, including Table S2.

Figure S2. Word clouds of the coded open responses.

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