

Emotion

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Awe in Nature Heals: Evidence From Military Veterans, At-Risk Youth, and College Students

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The power of nature to both heal and inspire awe has been noted by many great thinkers. However, no study has examined how the impact of nature on well-being and stress-related symptoms is explained by experiences of awe. In the present investigation, we examine this process in studies of extraordinary and everyday nature experiences. In Study 1, awe experienced by military veterans and youth from underserved communities while whitewater rafting, above and beyond all the other positive emotions measured, predicted changes in well-being and stress-related symptoms one week later. In Study 2, the nature experiences that undergraduate students had during their everyday lives led to more awe, which mediated the effect of nature experience on improvements in well-being. We discuss how accounting for people's emotional experiences during outdoors activities can increase our understanding of how nature impacts people's well-being.

Keywords: awe, well-being, nature experience, diary methodology, field research

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Everybody needs beauty as well as bread, places to play in and pray in, where nature may heal and give strength to body and soul alike.

—John Muir, *The Yosemite*, 1912

The writings of the naturalist John Muir center upon the common theme that nature both inspires awe and heals. Empirical evidence has separately supported these two effects of nature experience. For example, a meta-review of 59 review papers found that contact with nature can reduce stress and promote a more robust health profile (Hartig, Mitchell, de Vries, & Frumkin, 2014). Furthermore, nature has been shown to reliably and robustly elicit awe (Gordon et al., 2017; Piff, Dietze, Feinberg, Stancato, & Keltner, 2015; Shiota, Keltner, & Mossman, 2007; Valdesolo & Graham, 2014). However, no empirical study to date has united these two lines of inquiry. The aim of the present investigation is to test the hypothesis that nature promote well-being through awe.

Emotion as a Mechanism of the Effect of Nature Experience on Well-Being

The study of nature experience and well-being most typically has treated emotions as outcomes, measured before and after and examined for change. In this vein, research shows that people report more positive affect after time outdoors (for reviews see Bowler, Buyung-Ali, Knight, & Pullin, 2010; Haluza, Schönbauer, & Cervinka, 2014). However, no study has examined the different emotions that people have during their nature experiences. This is a critical shortcoming in light of mounting evidence demonstrating that specific emotions like awe, gratitude, fear, and compassion relate to well-being outcomes (Algoe, Haidt, & Gable, 2008; Folkman & Moskowitz, 2000; Gordon et al., 2017; Sin & Lyubomirsky, 2009). Experiences in nature are the provenance of many distinct emotions. For example, when ascending a high altitude peak one can experience awe at the expansive view (Keltner & Haidt, 2003; Shiota et al., 2007), fear at the threat of falling (Anderson, Monroy, & Keltner, 2017), contentment after a hearty meal by the campfire (Cordaro, Brackett, Glass, & Anderson, 2016), or pride at having accomplished an impressive feat (Tracy & Robins, 2007). A focus on specific emotions during nature experiences could illuminate how and why nature leads to reduced stress and increased positive functioning. By capturing both exceptional and daily experiences of nature, in the present work we test the hypothesis that awe is a mechanism that in part explains the influence of nature upon enhanced well-being.

Nature, Awe, and Well-being

Research suggests that nature is a powerful elicitor of awe, an emotion elicited by vast stimuli that do not fit into existing mental schema (Keltner & Haidt, 2003). For example, one study showed that when asked to recall a time they felt awe, people most often

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described nature experiences (Shiota et al., 2007). Moreover, experimental research has used nature videos (Gordon et al., 2017; Piff et al., 2015, Study 3; Valdesolo & Graham, 2014) and *in situ* experiences in nature (Piff et al., 2015, Study 5; Bai et al., 2017) to experimentally elicit high levels of awe.

Within this burgeoning science of awe, select studies find that experiences of awe promote well-being. For example, reading an awe-inspiring passage was shown to increase momentary life satisfaction (Rudd, Vohs, & Aaker, 2012) and in a daily diary study, nonthreatening experiences of awe led to reports of increased daily well-being (Gordon et al., 2017, Study 4). Moreover, awe has also been associated with more adaptive physiological profiles as indicated by lower markers of inflammation (Stellar et al., 2015) and greater activation of the vagus nerve (Gordon et al., 2017, Study 3). Taken together, these independent lines of research find that nature reliably elicits awe and that awe is related to improvements in well-being. However, no empirical work has tested the possibility that awe is a mechanism by which nature experience affects well-being.

To test this thinking, we not only assessed awe, but also other positive emotions that people might experience during time outdoors that have also been linked to well-being: gratitude, amusement, pride, contentment, and joy. For example, the cultivation of gratitude, an emotion thought to bolster supportive relationships (Algoe, 2012), has been shown to impact personal and social well-being (Emmons & McCullough, 2003; Lyubomirsky, Dickerhoof, Boehm, & Sheldon, 2011). The capacity to feel amusement has been linked to well-being outcomes generally (Martin, Puhlik-Doris, Larsen, Gray, & Weir, 2003), and also in people who had recently lost a spouse (Bonanno & Keltner, 1997; Keltner & Bonanno, 1997). Pride at having accomplished a worthy feat is thought to promote adaptive social functioning by motivating the seeking and maintenance of status, as well as communicating status to others (Cheng, Tracy, & Henrich, 2010; Tracy & Robins, 2007). Contentment, an emotion characterized by appraisals of perceived completeness, is theorized to be a central contributor to well-being (Cordaro et al., 2016). Finally, joy an emotion elicited by imminent reward, is thought to support the gathering of important resources (Ekman & Cordaro, 2011; Shiota, Neufeld, Yeung, Moser, & Perea, 2011). By assessing these five other positive emotions, all predictive of well-being, a key contribution of the current work is to demonstrate that awe experienced in nature predicts unique variance in well-being, above and beyond the effects of other positive emotions.

The Current Research

We aim to provide the first test of the hypothesis that awe mediates the relationship between nature experience and improved well-being. We do so in studies of both extraordinary and everyday nature experiences. In Study 1, we examined how the awe experienced by military veterans and youth from underserved communities during whitewater rafting trips predicted improvements in well-being and stress-related symptoms above and beyond the effects of other positive emotions. In Study 2, we examined the relationship between nature, awe, and well-being during people's everyday lives using a daily diary methodology. Across these two studies we tested three hypotheses. First, in keeping with a rich literature on the benefits of nature immersion (Hartig et al., 2014),

we predicted that experiences in nature, both during whitewater rafting trips (Study 1) and in daily life (Study 2), would be associated with improvements in well-being and stress-related symptoms. Second, we hypothesized that awe experienced both during whitewater rafting trips (Study 1) and in daily life (Study 2) would be related to better well-being and stress-related symptoms, above and beyond the effects of other positive emotions. Third, we hypothesized that awe would mediate the effect of nature experience on well-being (Study 2).

Study 1: Awe, Whitewater Rafting, and Well-Being

In Study 1, we examined the relationship between awe and well-being in the context of an extraordinary nature experience, a whitewater rafting trip. We recruited a sample of military veterans and youth from underserved communities in which a wide range of age, racial and ethnic backgrounds, and life experiences were represented. We tested our first two hypotheses in Study 1. First, we predicted that people would show improvements in longitudinal well-being and stress-related symptoms from baseline to follow-up, one week after the rafting trip. Second, building on the established link between awe and well-being (Gordon et al., 2017; Rudd et al., 2012) we predicted that awe reported during the rafting trip would be related to changes in longitudinal well-being and stress-related symptoms, above and beyond the effect of the other positive emotions measured: amusement, contentment, gratitude, joy, and pride.

Method

Participants. The sample consisted of 124 military veterans and youth from underserved communities (38% female) who participated in either 1-day or 4-day whitewater rafting trips organized by the Sierra Club Outdoors organization during the 2015 and 2016 summer whitewater rafting seasons. In total, 72 veterans and 52 youth were recruited. This sample is larger than that of recent studies examining awe (Piff et al., 2015; Stellar et al., 2018) and other emotions (Tracy & Matsumoto, 2008) in naturalistic contexts. Further sample details can be found in Section 1 in the online supplemental material. Findings from the 2015 cohort focusing on the coherence of subjective, expressive, and physiological components of fear have been reported previously (Anderson et al., 2017).

Procedure. Consent materials were collected before the rafting trip began, and research personnel were present to brief participants on the study and administer baseline measures that assessed demographics, personality, and well-being. Because of a strict schedule that included a safety training and a firm launch time to ensure the trip would be concluded while river conditions were safe, we had a very limited window of time to brief participants on the study and administer the baseline measure, which consisted of a single sheet of paper.

At the end of each day of rafting, participants completed a rafting diary in which they reported on emotions, cognitions, and social experiences they experienced that day. Participants on 1-day trips thus completed the rafting diary once, and those on 4-day trips (22.6% of sample) completed the rafting diary four times. One week after the rafting trips, follow-up measures were sent to participants either by e-mail, or posted mail,

according to their preference. Participants who completed the study protocol were given a \$25 gift certificate. This procedure was approved by the authors' institutional review board.

Measures. The complete rafting diary and longitudinal well-being instruments described in the following text can be found at <https://osf.io/6zfnq/>.

Rafting diary. At the end of each day of rafting, participants reported how much of each of six positive emotions that they felt during the day, selected to capture a wide array of distinct positive states (Shiota et al., 2017). In the case of participants who went on 4-day trips, the average of each item across all the diaries completed was used in analyses. Guided by past diary studies (Impett et al., 2012; Srivastava, Tamir, McGonigal, John, & Gross, 2009), each emotion was assessed with single items consisting of synonym clusters, on a scale from 0 (*none at all*) to 10 (*completely*). The following emotions and their synonym clusters were as follows: awe (*awe, amazed, wonder*; $M = 7.69$, $SD = 2.40$), amusement (*amused, having fun, laughing*; $M = 8.32$, $SD = 2.08$), contentment (*content, relaxed, peaceful*; $M = 7.55$, $SD = 2.26$), gratitude (*grateful, appreciative, thankful*; $M = 8.27$, $SD = 2.09$), joy (*joyful, excited, enthusiastic*; $M = 8.08$, $SD = 2.20$), and pride (*proud, sense of accomplishment, successful*; $M = 8.07$, $SD = 2.00$). We note that previous work has distinguished two facets of pride, authentic pride felt in response to achieving a worthy goal, and hubristic pride, which is rooted in narcissism and characterized by feelings of superiority that are not tied to actual achievement (Tracy, Cheng, Robins, & Trzesniewski, 2009; Tracy & Robins, 2007). Our operationalization of pride in the current work aimed to capture authentic pride, in Study 1 for example, the feelings of achievement of having completed a challenging day of whitewater rafting. To be consistent with how we discuss other emotions, however, in the current work we simply refer to it as *pride*.

Longitudinal well-being and stress symptoms. As our sample was comprised of people from at-risk populations, in addition to well-being measures we also included items measuring symptoms of post-traumatic stress disorder (PTSD) and stress. Because of time constraints, select items from the Satisfaction with Life Scale (SWLS; Diener, Emmons, Larsen, & Griffin, 1985), Mental Health Checklist (MHC-SF; Keyes, 2002, 2009), PTSD Checklist (PCL; Blanchard, Jones-Alexander, Buckley, & Forneris, 1996; Wilkins, Lang, & Norman, 2011), and the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983) were administered to participants. Participants responded to these items using a six-point scale ranging from 0 (*never*) to 5 (*every day*) to indicate the frequency of certain experiences in recent past. The baseline measures asked about experiences in the past month, and follow-up measures asked about experiences since the rafting trip. In the main text, results are presented using a composite consisting of the average of these 19 items with negatively framed items reversed scored (baseline: $\alpha = .84$; follow-up: $\alpha = .88$). Additional information about the individual measures that make up the composite including descriptive statistics are included in Section 1 in the online supplemental material.

Results

Overall, 70% of participants completed the follow-up assessment. Eighteen of the missing follow-up assessments were from a single youth trip due to loss of communication with the group at follow-up. Using *t* tests, we found that youth reported lower well-being than veterans at both time points ($t_s \geq 2.82$, $p_s \leq .006$), but there were no significant differences between veterans and youth in reported positive emotions in the rafting diary ($p_s \geq .13$). In all our analyses we controlled for participant status, that is, whether individuals were youth or veterans.

To test our first hypothesis that well-being would be higher at follow-up 1-week after the rafting trip compared to baseline, we conducted a repeated-measures analysis of variance with well-being composite measurements specified as a within-subjects factor. Consistent with our first hypothesis, we found that well-being at follow-up ($M = 3.24$, $SD = .78$) was significantly higher than baseline well-being ($M = 2.88$, $SD = .72$), $F(1, 95) = 51.14$, $p < .001$, $\eta_p^2 = .35$.¹ We also observed an interaction between participant status and time, such that while both youth and veterans demonstrated large and significant improvements from baseline, the improvement in well-being was significantly greater in youth, $F(1, 95) = 5.20$, $p = .025$, $\eta_p^2 = .052$.

In our second hypothesis, we predicted that awe, above and beyond other positive emotions, would be related to improvements in longitudinal well-being. To test this hypothesis, we conducted a hierarchical regression with three steps. In the first step we entered participant status and the baseline well-being composite as predictors and the follow-up well-being composite as the outcome, $R^2 = .54$, $F(2, 90) = 55.83$, $p < .001$. In the second step, we added awe reported in the rafting diary, which was positively related to improvements in well-being, $b = .06$, $t(89) = 2.81$, $p = .006$, 95% CI [.02, .11], $\beta = .20$. Furthermore, adding awe resulted in a significant improvement in the model, $R_{\text{change}}^2 = .04$, $F(1, 89) = 7.89$, $p = .006$. To stringently control for the effects of other positive emotions, in the third and final step we added all of the other positive emotions reported in the rafting diary to the model: amusement, contentment, gratitude, joy, and pride. In this model the relationship between awe and follow-up well-being remained significant, $b = .08$, $t(84) = 2.51$, $p = .014$, 95% CI [.02, .15], $\beta = .26$. None of the other positive emotions significantly predicted changes in well-being, $|b| \leq .11$, $p_s \geq .31$, and this step did not yield a significant change to the model, $R_{\text{change}}^2 = .02$, $F(5, 84) = .63$, $p = .68$. Taken together, these findings are consistent with our hypothesis that awe experienced during whitewater rafting would be related to improvements in well-being and stress-related symptoms, above and beyond the effects of other positive emotions.²

¹ This finding holds across individual measures. Analyses of individual measures can be found in the Section 2 in the online supplemental material. We found the largest effect for PTSD symptoms, $\eta_p^2 = .36$, and the smallest effect for the single happiness item, $\eta_p^2 = .05$.

² The same item used to assess daily life satisfaction in Study 2 was also assessed in the rafting diary in Study 1. However, it was not significantly related to change in longitudinal well-being, and so we did not test a mediation as we do in Study 2. Further information about this measure is given in Section 3 in the online supplemental material, and the relationship between each of the individual emotion items measured in the rafting diary with this item as well as the well-being composite are displayed in Table S3 in the online supplemental material.

Study 2: Nature Experience, Awe, and Well-Being in Everyday Life

In keeping with the literature on immersive nature experiences and well-being, Study 1 tested our hypotheses about awe and well-being in the context of what was, for many participants, a once-in-a-lifetime nature experience. Study 2 extended these findings by testing our hypotheses about nature experience, awe, and well-being in the context of people's everyday lives. In this first examination of the daily dynamics of nature experience, awe, and well-being, we used diary methodology to test if awe mediates the effect of nature experience on well-being in people's everyday lives. Nature experiences were captured in participants' narrative descriptions of events from their day, which minimizes bias due to demand characteristics and broadens the array of nature experiences considered. Well-being was measured at two levels of temporal resolution: a brief life satisfaction measure was administered daily, and longitudinal well-being was assessed using more stable measures before and after the diary period.

In Study 2 we tested four hypotheses. First, we predicted that participants would report higher daily life satisfaction on days they experienced nature. Second, we predicted that participants would report increased awe on days they experienced nature. Third, we expected that awe would be related to daily life satisfaction, above and beyond the other positive emotions measured that day: amusement, contentment, gratitude, joy, and pride. Fourth, we expected that awe would mediate the effect of nature experience on both daily life satisfaction and changes in longitudinal well-being.

Method

Participants and procedure. Participants were 119 undergraduate students ($M_{age} = 21.30$, $SD = 2.79$, 74.8% female) who participated in multiphase study exchange for credit in a psychology course. This sample size is comparable to that of previous studies examining experiences of awe in daily life (Gordon et al., 2017; Stellar et al., 2018). Participants first attended a laboratory session during which they gave informed consent, completed demographics and baseline measures of well-being, participated in a laboratory-based data collection not related to the current research, and were then briefed on the diary protocol, which began the same day. During the diary period, participants were sent a link to the diary survey via e-mail every night for 14 consecutive days. Each diary began with Likert-type questions that prompted participants to report on emotions, social experiences, and thoughts they experienced that day. At the end of the diary participants were asked to write short narratives about an experience of awe or other positive emotion they experienced that day. After the final diary entry, participants completed follow-up longitudinal well-being measures. This procedure was approved by the authors' institutional review board.

Measures. The complete diary and longitudinal well-being measures described in the following text can be found at <https://osf.io/6zfnq/>.

Diary measures. In each diary entry, participants rated how much they experienced a number of thoughts and feelings they had that day on an 11-point scale from 0 (*not at all*) to 10 (*completely*).

Positive emotions. With single items composed of synonym clusters, participants rated how much of each of six positive

emotions they experienced each day: awe (*awe, amazed, wonder*; $M_{across\ diary} = 2.69$, $SD = 1.76$), amusement (*amused, having fun, laughing*; $M_{across\ diary} = 5.13$, $SD = 1.76$), contentment (*content, relaxed, peaceful*; $M_{across\ diary} = 4.88$, $SD = 1.56$), gratitude (*grateful, appreciative, thankful*; $M_{across\ diary} = 5.41$, $SD = 1.96$), joy (*joyful, energetic, enthusiastic*; $M_{across\ diary} = 5.43$, $SD = 1.72$), and pride (*proud, sense of accomplishment, successful*; $M_{across\ diary} = 4.06$, $SD = 1.66$).

Life satisfaction. Daily life satisfaction was measured with a single item: "How satisfied were you with your life today?" ($M_{across\ diary} = 6.02$, $SD = 1.72$).

Coded nature experiences from narratives. After reporting on the overall emotions and well-being they felt that day using the Likert-style items described above, participants were asked to write a short narrative about an experience they had that day. The narrative prompt asked participants to write about an experience of awe if they had one that day, and if not, alternatively to write about the most positive event of the day. If participants chose the latter, after writing the narrative they were shown a list of emotions and asked to indicate which ones characterized the experience. The complete diary instructions can be found at <https://osf.io/6zfnq/>.

We used instructions that mention awe specifically because we anticipated that a prompt that only asked participants to write about a positive experience might result in underreporting of experiences of awe for two reasons. First, we expected that experiences of awe would occur relatively less frequently than experiences of other positive emotions such as amusement. This might result in participants writing more often about emotions other than awe that they experience more frequently due to availability heuristics. Second, as experiences of awe often include elements of threat (Gordon et al., 2017) they might be overlooked by people instructed to think about positive events of their day. Participants chose to write about awe in 271 (17.7%) diaries. Of the remaining 82.3% of the narratives that described positive events, participants rated 578 (37.8%) as describing joy, 795 (51.9%) as contentment, 454 (29.7%) as pride, 716 (46.7%) as gratitude, and 511 (33.4%) as amusement. These data are consistent with our expectations that awe would occur less frequently than other positive emotions.

Trained coders read each diary narrative entry for whether it referred to nature (coded 1) or not (coded 0). Of the 1,519 diary entries, 182 (12%) involved nature. The average number days participants mentioned experiencing nature was 1.59 ($SD = 1.64$) and ranged between zero and eight. Table S4 in the online supplemental material depicts the frequencies of the number of diary entries coded as nature experiences for each participant. Of the 182 nature narratives, 116 (63.7%) were from narratives about experiences of awe and 66 (36.3%) were from narratives about other positive emotions. Coded nature experiences included watching the sun set, appreciating the beauty of campus on a sunny day, and noticing blooming flowers. As an example, one participant wrote the following: "Today the sunset was beautiful. It covered so much of the sky and had such deep reds, oranges, and yellows. I stopped and looked out the window and enjoyed it until it ended. It was a moment of peacefulness."

Longitudinal well-being. Psychological and social well-being were assessed using 16 items adapted from the Satisfaction with Life Scale (SWLS; Diener et al., 1985) and the Mental Health Continuum (MHC-SF; Keyes, 2002). In the main text, we present analyses of composites formed by standardizing and averaging the

items at baseline before the diary period started ($\alpha = .90$) and follow-up immediately after the last diary entry ($\alpha = .93$). Descriptive statistics of individual well-being measures used in the composite can be found in Section 4 in the online supplemental material.

Results

Four participants dropped out of the study at the beginning of the diary period: two of them completed one diary entry and the other two completed none. The remaining 115 participants submitted at least seven entries each, generating 1,529 entries out of a possible 1,610 (95%) during the diary period. Of these participants, 108 (94%) completed the follow-up measures. Correlations between diary measures of emotion, daily life satisfaction, and follow-up well-being can be found in Table S5 in the online supplemental material. Because of the structure of the data—diary entries nested within participants—to test our first three hypotheses we implemented a multilevel modeling approach with the MIXED procedure in SPSS (v. 22) using restricted maximum likelihood estimation and specifying participant intercepts as random.

To test our first hypothesis, we first examined the effect of nature experience on daily life satisfaction. We specified daily life satisfaction as the outcome, with the dichotomous coded nature experience variable as a fixed effect. Consistent with our prediction, we found that on days people wrote about experiencing nature they reported higher satisfaction with life ($M = 7.56$, $SE = .21$) than on non-nature days ($M = 6.95$, $SE = .16$), a significant effect, $b = .61$, $t(1,440.21)$, $p < .001$, 95% CI [.30, .92].

To test our second hypothesis that nature experiences would be more strongly related to daily reports of awe than other positive emotions, we examined the relationship between coded nature

experiences and each of the positive emotions reported in the diary separately. Although a total of five emotions were significantly related to coded nature experiences, as Figure 1 illustrates, the 95% confidence interval of the effect of coded nature experience on awe does not overlap with that of the other emotions. This means that statistically, the link between nature experiences and awe was significantly stronger than the relationships between nature experiences and all of the other positive emotions assessed in the diary. Furthermore, the point estimate of the effect is more than twice as large for awe as it is for the other positive emotions.

To test our third hypothesis, we entered all six positive emotions into a model predicting daily life satisfaction. Analyses showed that awe was positively related to daily life satisfaction, $b = .04$, $t(1,508.95)$, $p = .017$, 95% CI [.01, .07]. We note that all of the other positive emotions were significantly related to daily life satisfaction as well (see Table S5 in the online supplemental material). However, consistent with our hypothesis results showed that awe, above and beyond the effects of other positive emotions, was related with daily life satisfaction.

Having established that daily experiences of awe are related to both nature experience and daily life satisfaction above and beyond the effect of other positive emotions, we next tested our fourth hypothesis that awe would mediate the effect of nature experience on well-being. Because we assessed well-being at two different temporal resolutions—life satisfaction was briefly assessed daily and longitudinal well-being was assessed with more stable measures before and after the diary period—we conducted two mediation analyses. First, we tested mediation within the diary with daily life satisfaction as the outcome. Next, we used a serial mediation to test if the dynamics captured in the diary in turn predicted changes in longitudinal well-being. Specifically, we tested an indirect effect of daily nature experience on changes in

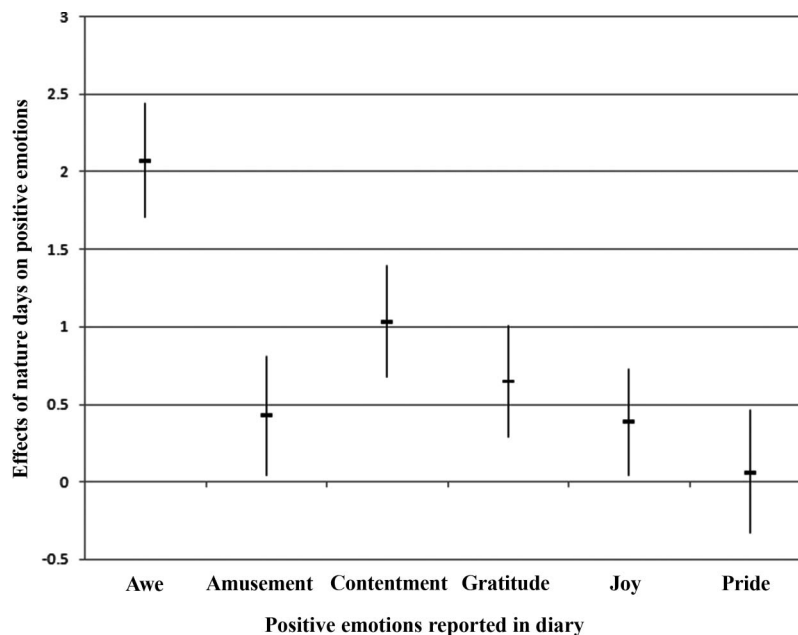


Figure 1. The effect of daily nature experience on the six positive emotions reported in the diary. Effects are unstandardized and bars indicate 95% confidence intervals.

longitudinal well-being produced in sequence through daily experience of awe and daily life satisfaction.

We first tested our fourth hypothesis at the daily level using a multilevel mediation approach with the MLMED macro for SPSS (Rockwood & Hayes, 2017). In these analyses, predictors were person-centered. Coded nature experience was specified as the independent variable, awe as the mediator, and daily life satisfaction was the dependent variable. Consistent with our hypothesis, we found a significant indirect effect of nature experience on daily life satisfaction through awe, $b = .62$, $SE = .07$, $z = 8.61$, $p < .001$, 95% CI [.48, .76]. The complete model with effects of each path is illustrated in Figure 2.

Given that awe was positively related to other positive emotions assessed in the diary, we conducted further exploratory analyses to test if there was an effect of nature experience on daily life satisfaction through awe, but not other positive emotions. To this end, we tested each of the other positive emotions as the mediator of this effect. Of these five emotions, we found that two were also significant mediators: contentment, $b = .42$, $SE = .08$, $z = 5.01$, $p < .001$, 95% CI [.26, .59]; and gratitude, $b = .26$, $SE = .08$, $z = 3.15$, $p = .0016$, 95% CI [.10, .42]. To test the mediating effect of awe beyond these other emotions, we then specified a model with awe, contentment, and gratitude entered simultaneously as parallel mediators. This analysis showed that the significant indirect effects of all three emotions remained: awe, $b = .26$, $SE = .05$, $z = 5.73$, $p < .001$, 95% CI [.18, .36]; contentment, $b = .27$, $SE = .06$, $z = 4.83$, $p < .001$, 95% CI [.16, .38]; and gratitude, $b = .16$, $SE = .05$, $z = 3.09$, $p = .002$, 95% CI [.06, .27]. These results support our hypothesis that nature experience has an effect on well-being through awe even when controlling for other positive emotions, but also suggest that there may be pathways through other positive emotions as well.

Given that the effect of daily nature experience on life satisfaction was mediated by awe, we then tested a serial mediation with longitudinal well-being as the outcome. Toward this end, we used the PROCESS macro for SPSS to test a serial mediation (Hayes, 2012; Model 6) such that the effect of daily nature experience on change in longitudinal well-being is mediated by daily awe and daily life satisfaction in sequence (see Figure 3). As longitudinal well-being was measured at the participant level, for these analyses the variables assessed daily were aggregated across the diary period. We thus entered the aggregate nature experience variable, a count of how many days people wrote about experiencing nature, as the independent variable with follow-up longitudinal well-being as the outcome with baseline well-being as a covariate, and the aggregated daily awe and daily life satisfaction variables as sequential mediators.

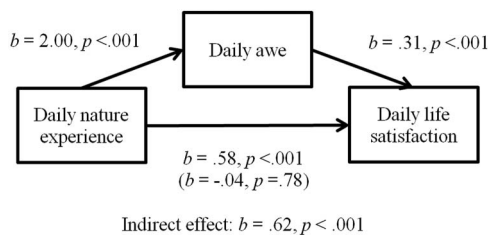


Figure 2. Mediation model: The indirect effect of nature experience on life satisfaction through awe in the diary in Study 2.

Consistent with our hypothesis, results showed a significant serial mediation through the proposed pathway, $b = .05$, $SE = .02$, 95% CI [.02, .10]. The more nature experiences people had over the 14-day diary period, the more daily awe they experienced, the greater daily life satisfaction they reported, which in turn was related to greater improvements in longitudinal well-being at follow-up. As Figure 3 shows, in each step of the sequential mediation the added predictor was significantly related to the outcome; and, importantly, the previously entered predictors were not significant. Furthermore, as described in Section 5 of the supplementary materials, alternate ordering of the mediators and testing each mediator by itself did not yield significant indirect effects, lending more support to the sequence that we hypothesized.

The results from Study 2 suggest that as students navigate the academic and social demands of a busy semester, daily doses of nature elicit awe and improve well-being, above and beyond the effects of other positive emotions.

Discussion

Empirical studies are increasingly documenting that immersion in nature predicts improvements in myriad health and well-being outcomes (Hartig et al., 2014). Little is known, however, about the emotional mediators of the salutary effects of nature. Guided by recent advances in the science of awe, we documented for the first time that the awe that people feel during both extraordinary and daily nature experiences predicts unique variance in improvements in well-being and stress-related symptoms above and beyond the effects of other positive emotions. In Study 1, we found that the awe that military veterans and youth from underserved communities felt while whitewater rafting predicted improvements in longitudinal improvements in well-being and stress-related symptoms. In Study 2, we showed that when people experience nature during their daily lives, they report higher levels of awe and more daily life satisfaction, which in turn predicts improvements in longitudinal well-being. This research builds upon recent studies of the well-being benefits of awe (Gordon et al., 2017; Rudd et al., 2012), and highlights how this emotion might be a mechanism of how nature improves health and well-being.

While both Studies 1 and 2 showed that even when controlling for other positive emotion, awe predicted improvements in well-being, exploratory analyses in Study 2 suggest that other positive emotions experienced in nature may also impact well-being. Specifically, we found that reported contentment and gratitude, in addition to awe, also mediated the effect of nature experience on daily life satisfaction. The semantic similarities between the contentment and life satisfaction items limits the extent to which this finding can be interpreted. However, the effect of gratitude is consistent with the growing literature showing how the cultivation of gratitude can increase well-being (Emmons & McCullough, 2003; Lyubomirsky et al., 2011). Further research is needed to examine how gratitude functions in the context of nature experiences.

Although the present investigation highlighted the benefits of nature-related awe during both extraordinary and daily experiences in nature, it is important to bear in mind that the findings were longitudinal and not experimental, limiting the ability to infer causality. The present investigation's findings are also limited by

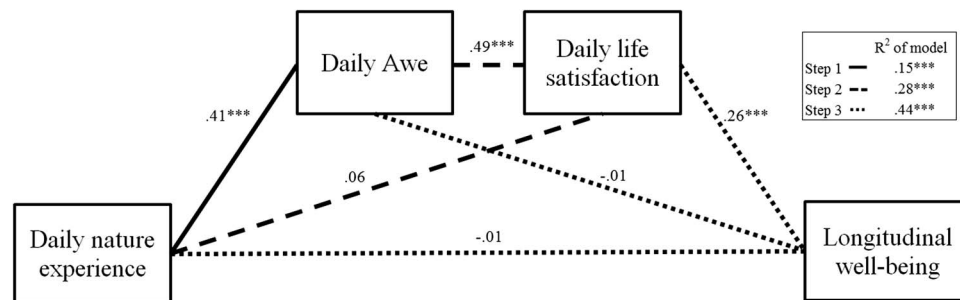


Figure 3. Study 2 sequential mediation model. Distinct line styles represent different steps in the model. Numbers above lines are unstandardized coefficients of that path. *** $p < .001$.

our inability to control for potential confounds—for example, that nature experiences may involve time off from work or school—that cloud the inferences drawn from the present findings. To move the field forward, carefully designed experiments are needed that compare nature experience with active controls that match for factors that likely affect health, such as physical exertion.

Conclusion

For John Muir, the outdoors were a source of both restoration and awe. In the current study, we captured both these properties of nature experience, showing for the first time that awe mediates the effect of nature experience on well-being. These findings suggest that awe may be one active ingredient in the remedy that is time spent outdoors.

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