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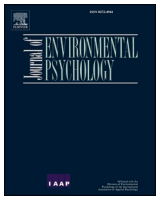

Nature's path to thinking about others and the surrounding environment

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ABSTRACT

Research has shown differences in pro-social and pro-environmental attitudes after exposure to different physical environments. It is unclear whether these perspective shifts are associated with changes in conscious thoughts and feelings about other people and the environment. In Study 1, we used a within-subject experiment to measure social and environmental thought content throughout 1-h environmental explorations of a nature conservatory and an indoor mall. At three survey time points, participants (N = 86, undergraduates and community members) reported whom they were thinking about and how connected they felt to the physical and social environment. Using Bayesian multi-level models, we found that while visiting the conservatory, participants were less likely to think about themselves, felt closer to people nearby and around the world, and felt higher connectedness to their social and physical environment. In Study 2, we used a correlational design to investigate the association between perceived naturalness of city parks and feelings of connection to nearby others and the physical environment while visiting. Participants (N = 303, Chicago residents) reported feeling higher levels of connection to nearby people and the physical environment when they were visiting city parks rated as more natural. These studies further our understanding of the ways in which natural environments influence conscious thoughts and feelings about the social and physical environment.

Public spaces, such as parks, plazas, and community centers, are important and highly influential places in contemporary human social life. These spaces are composed of social and physical elements that can influence physical and mental health, cognitive and affective states, and overall well-being (Benita, Bansal, & Tunçer, 2019; Cattell, Dines, Gesler, & Curtis, 2008; Francis, Wood, Knuiman, & Giles-Corti, 2012; Giles-Corti et al., 2005; Trawalter, Hoffman, & Palmer, 2021). Within the realm of physical environments, natural environments and stimuli have been shown to be especially salubrious for health and well-being (Berman, Kardan, Kotabe, Nusbaum, & London, 2019, Berman, Stier, & Akcelik, 2019; Bratman et al., 2019; Hartig, Mitchell, de Vries, & Frumkin, 2014; Kardan et al., 2015; Schertz & Berman, 2019). For example, urban greenspaces provide benefits at the community level by supporting social engagement, social capital, and place attachment (Arnberger & Eder, 2012; Jennings & Bamkole, 2019). Urban greenspaces also provide places for neighbors to meet and establish social ties (Coley, Sullivan, & Kuo, 1997; Peters, Elands, & Buijs, 2010; Sullivan, Kuo, & DePooter, 2004).

There is a robust literature on the psychological effects of being in natural environments. One category of effects focuses on social orientation. Considering how environments can contribute to social orientation is especially important given that many people feel increasingly

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disconnected from others (Feng & Astell-Burt, 2022; Konrath, 2013). Thinking about oneself is not inherently bad, however orientation towards others and prosocial purpose may improve health and reduce loneliness (Bains & Turnbull, 2019). Exposure to natural environments, on both acute and long-term bases, has been shown to positively influence pro-social behaviors and attitudes (Goldy & Piff, 2020). For example, a study in which people were directed to either notice natural or human-built elements of their environment found that those in the nature group reported greater pro-social orientation and connection to others at the end of a two-week period (Passmore & Holder, 2017). In another study, people who viewed nature scenes, compared to human-made scenes, reported stronger prosocial and other-focused values (Weinstein, Przybylski, & Ryan, 2009).

In addition to pro-social orientation, increased pro-environmental orientation has also been associated with exposure to natural environments. In an observational study, participants who visited nature more often reported engaging in more household pro-environmental behaviors, a relationship which was moderated by nature connectedness (Martin et al., 2020). Another study found that interacting with natural environments for psychological restoration was associated with self-reported improvements in ecological behavior, even when controlling for concern for the environment (Hartig, Kaiser, & Strumse, 2007). Given concerns, particularly in Western society, about disconnection from the natural world (Hartig & Kahn, 2016; Kesebir & Kesebir, 2017), as well as issues of climate change and the destruction of the natural environment, investigating ways to increase connection to the natural world is of utmost importance.

In the current studies, we sought to investigate how environmental effects on social and environmental orientation might be reflected in conscious thoughts and feelings while exploring public spaces with different levels of naturalness. What people spend their time thinking about forms an important part of their lived experience (Baumeister, Hofmann, Summerville, Reiss, & Vohs, 2020; Larson & Csikszentmihalyi, 2014; Sripada & Taxali, 2020), and thought content is important to examine to fully understand the myriad effects of the external environment on human health and well-being (Berman, Kardan, et al., 2019; Berman, Stier, & Akcelik, 2019). Previous work has found relationships between thought content and the visual features in one's physical environment (Schertz et al., 2018, 2020), suggesting that the surrounding environment can influence conscious thoughts.

The dominant psychological theories explaining the benefits of natural environments on cognitive and affective processing (i.e., attention restoration theory (Kaplan, 1995), stress reduction theory (Ulrich et al., 1991), perceptual fluency account (Joye & van den Berg, 2011) do not address socially or environmentally focused outcomes, focusing instead on general affective and cognitive processes. One recent theory, relational restoration theory (Hartig, 2021), focuses on how natural environments may restore access to social support when multiple people experience the environment at the same time, which touches on connection to other people, but still does not directly focus on how individuals' social and environmental thoughts are shaped by their surrounding physical environments. Studies directly focused on this topic will build a body of knowledge to help update the current theories or develop new theories in this area.

Examining thought content directly may show if people consciously have more pro-social or pro-environmental thoughts when in natural environments. In terms of thought content and feelings, pro-social attitudes and orientation towards others may manifest in several ways. First, people may think less about themselves, and more about other people, or more about themselves together with other people, in a natural environment. Second, they may feel more connected to their social environment. And third, they may feel closer to others, such as family and friends, people in the surrounding environment, or even people around the world. Increased environmental orientation may result in feeling closer to the surrounding physical environment as well as having more thoughts about the physical surroundings, when in a natural environment. We conducted two studies to examine these possibilities.

In Study 1, we used a within-person experimental design and experience sampling methodology to measure differences in social and environmental thought content throughout a 1-h environmental exploration of a nature conservatory and a large indoor mall to specifically address the following research questions.

1) Do people have more socially oriented thoughts and feelings while in a natural public space compared to a non-natural public space, as operationalized by: a) fewer thoughts about themselves and more thoughts about other people or themselves with other people, b) greater feelings of closeness to others, and c) higher connection to their social environment?
2) Do people have more environmentally oriented thoughts and feelings while in a natural public space compared to a non-natural public space, as operationalized by: a) higher connection to their physical environment and b) more thoughts about their physical surroundings?

Experience sampling methods such as ecological momentary assessment generate structured reports about what people are thinking and feeling throughout the day by asking them in real-time (Larson & Csikszentmihalyi, 2014; Stone & Shiffman, 1994). Short-term experience sampling studies, for example, covering one to 2 h, have been used to get more intensive reports of thoughts in specific environments (Doherty, Lemieux, & Canally, 2014). By surveying participants multiple times over their walk, we could examine how quickly differences in thought emerged between the two environments. The results reported in Study 1 are a subset of broader measures we collected during this study, with results for environmental effects on affect and working memory, for example, being reported in Schertz et al. (2022). As reported in that manuscript, we found that people are more likely to report positive thoughts and thoughts about the past while in the conservatory, while they are more likely to feel impulsive and report thoughts about the future while in the mall. Additionally, participants showed improvements in working memory, as measured by a dual 2-back task, after the conservatory visit compared to the mall visit, which is consistent with other studies (Berman, Jonides, & Kaplan, 2008; Bratman, Daily, Levy, & Gross, 2015; Cimprich & Ronis, 2003; Dadvand et al., 2015).

In Study 2, we used a correlational design to examine the association between perceived naturalness and feelings of connectedness to a) nearby people and b) the physical environment during visits to hundreds of city parks. Given that there are many differences between the nature conservatory and mall in Study 1, this informs our hypothesis that naturalness is a key feature contributing to differences in feelings of social and environmental connection. The results reported in Study 2 are part of a larger study on environmental impacts throughout the city of Chicago (https://osf.io/pjfcd/). Given recent findings showing that social context influences social thinking (Mildner & Tamir, 2021), supplemental findings for both Study 1 and Study 2 investigated how the number of people in the surroundings interacted with the influence of the environments on social thought. Additionally, as some people may be more or less sensitive to their environment (Aron & Aron, 1997), we explored whether individual personality traits, such as rumination and impulsivity, were associated with social and environmental thoughts.

1. Study 1

1.1. Material & methods

1.1.1. Participants

A total of 99 participants participated in the study from October 2018 through April 2019. Ten participants did not return for the second session of the two-part study. Data collection issues resulted in the loss of three participants' data, leaving full analyzable data for 86 participants. Participants (mean age = 21.57 years, SD = 3.79 years, Range 18–39)

were either University of Chicago students or adults from the surrounding communities recruited through Facebook, flyers posted in the community, and the university's research participation system. There were 39 men, 58 women, and 2 participants who selected 'other' for gender. In terms of ethnicity, 31 participants identified as white/Caucasian, 31 identified as Asian/Asian American, 16 identified as Hispanic, Latino, or Chicano, 15 identified as Black/African American, 5 identified as multiple ethnicities and 1 participant identified as another race/ethnicity. In the final sample of 86 participants (mean age 21.60 years, SD = 3.78 years, Range 18–39), there were 32 men, 53 women, and 1 participant who selected 'other' for gender. Participants were paid $74 to complete the study. This research was approved by the Institutional Review Board of the University of Chicago. Sample size was determined primarily through resource constraints (e.g., time, money) and is similar to other studies examining the effects of nature exposure (McMahan & Estes, 2015). No data analysis was performed until after data collection was finished.

1.1.2. Locations

The nature conservatory study location was the Garfield Park Conservatory (referred to as 'conservatory' throughout) located in the Garfield Park neighborhood of Chicago (https://garfieldconservatory.org). The mall location was the Water Tower Place mall (referred to as 'mall' throughout) located in the Near North neighborhood of Chicago (https://www.shopwatertower.com/en.html). Fig. 1 shows example images from the spaces.

1.1.3. Procedure

The study was conducted over two sessions, spaced one week apart. The order of environments (i.e., conservatory and mall) was random and counter-balanced across participants. There was a maximum of 12 participants in each study session, due to practical limitations in transporting participants to the testing locations and the need to maintain a manageable ratio of participants to research assistants. Participants completed the trait questionnaires online via before arriving to the first session. All tasks during the study sessions were completed on Moto G5 Android cell phones.

When participants arrived at the laboratory building for each session, they were met by research assistants and directed to a shuttle bus. Research assistants collected participants' personal mobile devices and distributed the experimental cell phones. Participants then completed the baseline survey on the bus while it was stationary at the laboratory building. The shuttle bus then drove participants and research assistants to one of the study locations. Both study locations were approximately 30 min away from the laboratory.

Upon arrival at the study location, participants were instructed to explore the environments and answer survey questions on the experimental cell phone when indicated. Participants were prompted by a timer on the cell phone to complete the ambulatory survey after 20 min (Survey 1), 40 min (Survey 2), and 60 min (Survey 3). When they completed the third survey, they were prompted to meet the research assistants at the entrance. The shuttle bus then drove everyone back to the laboratory building. Each session lasted approximately 2–2.5 h. Fig. 2 shows a diagram representation of the study procedure.

1.1.4. Survey questions

1.1.4.1. Trait questionnaires. Trait questionnaires were completed at home by participants when they signed up for the study. In addition to providing demographic information, participants responded to a short form Big Five inventory (mini-IPIP) (Donnellan, Oswald, Baird, & Lucas, 2006), the Reflection-Rumination Questionnaire (RRQ) (Trapnell & Campbell, 1999), the Subjective Vitality Score (SVS) (Ryan & Frederick, 1997), the Valuing Emotions (VE) scale (Mangelsdorf & Kotabe, 2017), the Trait Rash Impulsivity Scale (TRIS) (Mayhew & Powell, 2014), and the 3-item loneliness scale (Hughes, Waite, Hawkley, & Cacioppo, 2004). Cronbach alphas for composite trait variables are reported in Supplemental Table A8; all were in the acceptable to good range. Analyses of trait variables are reported in Appendix A.

1.1.4.2. Baseline questionnaire. Upon arrival to each study session, before being transported to the study locations, participants completed the baseline questionnaire regarding their recent thoughts and feelings.

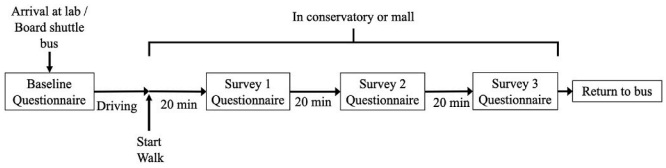

Fig. 2. Study procedure.

Fig. 1. Example images of Garfield Park Conservatory (left) and Water Tower Place mall (right). Images from Wikimedia Commons (Jrissman, 2010; Kenraiz, 2016).

Participants responded to the question "Was [your most recent] thought mostly about yourself, mostly about others, about yourself and others, or not about people?" These responses are mutually exclusive; thus, participants could only select one response. They also responded to the question "How close do you feel to the following groups: friends and family, people in your surroundings, people around the world?" and "How much do you feel connected to the [physical/social] environment around you?" Due to a coding error, Likert scales in the baseline questionnaire went from 0 to 7 while Likert scales in the ambulatory questionnaire went from 0 to 10. For all analyses, baseline responses were rescaled to 0–10. The participants were allowed to define each term in the questions for themselves, as we did not further define any of the concepts.

1.1.4.3. Ambulatory questionnaire. While walking around the study locations, participants completed the ambulatory survey three times. These surveys included the same questions as the baseline questionnaire, with an additional question that asked how many people were visible around them.

1.1.5. Statistical analyses

Statistical analyses were conducted in a Bayesian framework using multi-level models, with participant as a random/varying intercept. Continuous dependent variables were analyzed using linear regression. Categorical dependent variables (i.e., self/other focus of thought) were analyzed using logistic regressions. In all models, the independent variables were the interaction term between condition (i.e., conservatory and mall) and survey/timepoint (i.e., Baseline, Survey 1–3), including 8 time points in total. Main effects for condition were not included as the baseline survey for each condition was taken before participants were transported to the two environments, thus resulting in an uninterpretable main effect.

Regularizing priors were used for all models. Regularizing priors prevent models from overfitting to the sample by slowing the rate of learning from the data. We do not have assumptions for the priors based on previously collected data, thus regularizing priors is most appropriate. This, in combination with mixed effects modeling makes overfitting, and thus finding spurious effects, less likely. Sensitivity analyses (see Appendix A) were conducted to confirm results were robust to chosen priors. Full specifications of the models, including their priors, are shown in Table 1. Each model was run with 10,000 draws and 1000 warmup draws for four Markov Chain Monte Carlo (MCMC) chains, for a total posterior distribution of 36,000 post-warmup draws. Posterior distributions were summarized by reporting the 89% percentile intervals (PI). PIs are also referred to as quantile intervals and indicate the probability mass centered around the mean of the posterior distributions. Since PIs are not the same as frequentist confidence intervals, the 89th percentile interval was chosen to avoid both conscious and subconscious attempts at hypothesis testing that may occur if presented with a conventional 95% interval, as suggested by McElreath (McElreath, 2020). Bivariate correlations between dependent measures are reported in Supplemental Figure A1.

Table 1
Bayesian multi-level models.

Model for feelings of closeness and connection (linear)	Model for thoughts about self and others (logistic)	Explanation
$Response_i \sim \text{Normal}(\mu, \sigma)$ $\mu_i = 1 + \beta_{\text{condition*survey[j]}} + \alpha_{\text{participant[i]}}$	$Response_i \sim \text{Binomial}(1, p_i)$ $\text{logit}(p_i) = 1 + \beta_{\text{condition*survey[j]}} + \alpha_{\text{participant[i]}}$	Likelihood Regression Model
$\beta_j \sim \text{Normal}(0, 0.5)$, for $j = 1$–8	$\beta_j \sim \text{Normal}(0, 0.5)$, for $j = 1$-8	Prior for betas (2 conditions by 4 time points = 8 combinations)
$\alpha_{participant[i]} \sim \text{Normal}(\overline{\alpha}, \sigma_\alpha)$, for $i = 1 - 86$	$\alpha_{participant[i]} \sim \text{Normal}(\overline{\alpha}, \sigma_\alpha)$, for $i = 1 - 86$	Adaptive prior for each participant (N = 86)
$\sigma \sim \text{Exponential}(1)$		Prior for SD
$\overline{\alpha} \sim \text{Normal}(5, 1.5)$	$\overline{\alpha} \sim \text{Normal}(0, 1.5)$	Prior for Average Participant
$\sigma_\alpha \sim \text{Exponential}(1)$	$\sigma_\alpha \sim \text{Exponential}(1)$	Prior for SD of participant

We used a Bayesian analysis framework instead of traditional frequentist approaches because it offers many benefits. One benefit of this Bayesian approach is that we are able to generate estimates and credible intervals for any derived parameter, and differences, ratios and novel parameter combinations can be directly computed from the posterior distribution. The focus of our approach is on parameter estimation rather than binary inference. A second benefit is that the Bayesian approach allows us to compute computationally robust estimates of parameter values and their credible intervals, which do not depend on large-N approximations or on the number of intended tests (Kruschke, 2021). Additionally, credible intervals in Bayesian analysis, unlike confidence intervals of frequentist statistics, are in line with intuitive understandings of probability such that they indicate how likely a parameter has a value within that interval (Pek & Van Zandt, 2020) and not how extreme a parameter estimate is based on imaginary resampling of the data. Finally, with a Bayesian approach we can select regularizing priors that prevent the model from overfitting, thus increasing the likelihood of the model generalizing to out of sample data. As overfitting has been proposed as a key contributor to psychology's replication and generalizability crisis (Nosek et al., 2022; Yarkoni, 2022), a Bayesian approach which minimizes this risk is likely to lead to more reproducible results.

1.1.6. Transparency and openness

Data and analysis code are available at https://osf.io/cu6jr/. Models were run in R 4.1.1 (R Core Team, 2017) using the 'brms' package (Bürkner, 2017). This study's design and its analysis were not pre-registered. Additional dependent measures were collected during this study that are not reported here. The full list of dependent measures is shown in Supplemental Table 1. Results for some of the additional dependent measures (including, for example, working memory, affect, and thought valence) are reported in (Schertz et al., 2022), which uses data from the same study.

1.2. Results

1.2.1. Socially oriented thoughts

1.2.1.1. Thoughts of self and others. Participants were less likely to report thoughts about themselves in the conservatory compared to the mall during all ambulatory surveys, see Fig. 3a. After being in the environment for ~20 min (i.e., at Survey 1), the odds ratio between the two settings was 2.05 (i.e., participants were 2.05 times more likely to think about themselves in the mall vs. the conservatory), 89% PI [1.42, 2.85], with 99.9% of the MCMC samples showing an odds ratio greater than one. In probability terms, this was a difference of 24% probability of self-focused thoughts in the conservatory and 47% probability of self-focused thoughts in the mall. After approximately 40 min (Survey 2), the probability of self-focused thoughts was 29% in the conservatory and 38% in the mall, with a modeled odds ratio of 1.39 (89% PI [0.96, 1.91]), with 92.3% of the MCMC samples showing an odds ratio greater than one. After 60 min (Survey 3), the probability of self-focused thoughts was 27% in the conservatory and 54% in the mall, with an odds ratio of 2.03 (89% PI [1.46, 2.76]), with 100% of the MCMC samples showing an odds ratio greater than one.

When participants did think about themselves in the conservatory, it was often as part of a social relationship. That is, there was also evidence, though weaker, that participants reported more thoughts about 'themselves and others' throughout the conservatory walk compared to

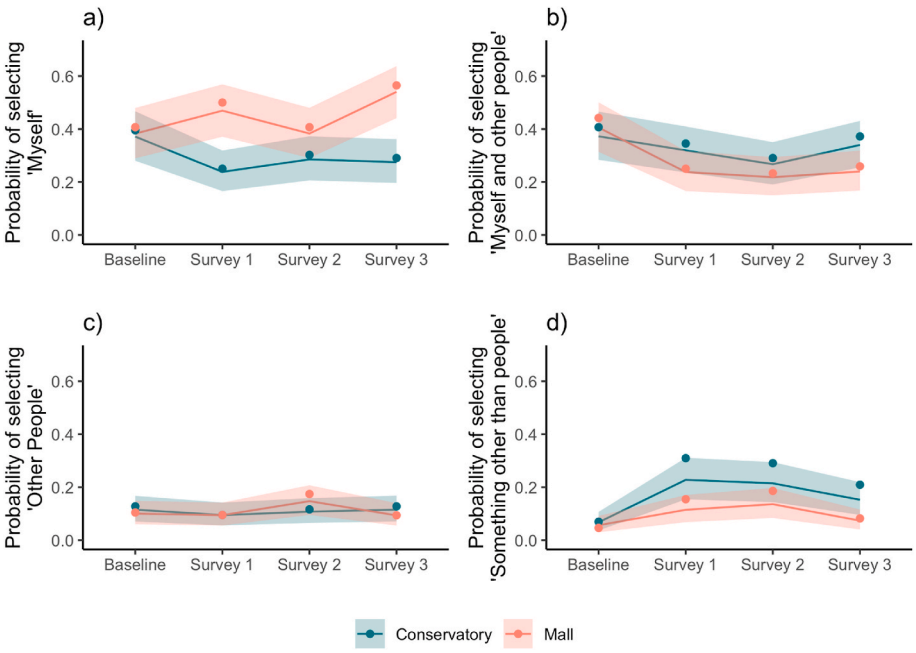

Fig. 3. Observed and modeled selection of a) self, b) self and others, c) others, and d) non-interpersonal focused thinking. Points are observed probabilities from the raw data. The fitted line is the logistic regression model's predicted estimate. The shaded area represents the 89th percentile interval of the posterior distribution.

the mall walk (Fig. 3b). At 20 min, the odds ratio between conservatory and mall was 1.40 (89% PI [0.93, 2.00]) with 90.2% of the MCMC samples showing an odds ratio greater than one. At 40 min, the odds ratio was 1.27 (89% PI [0.82, 1.83]), with 79.6% of the MCMC samples showing an odds ratio greater than one. At 60 min, the odds ratio was 1.47 (89% PI [0.99, 2.07]), with 94% of the MCMC samples showing an odds ratio greater than one.

There was no evidence of a conditional difference for reporting thoughts about only other people at any survey (Fig. 3c). At 20 min, the odds ratio was 1.10 (89% PI [0.54, 1.80]. At 40 min, the odds ratio was 0.76 (89% PI [0.42, 1.24], and at 60 min, the odds ratio was 1.32 (89% PI [0.69, 2.20]). Results for the remaining option, non-social thoughts, are discussed in Section 1.2.2.2.

1.2.1.2. Feelings of closeness to others. Participants reported feeling closer to people around the world while in the conservatory compared to the mall at all three survey timepoints, Fig. 4a. On a 10-point scale, the posterior distribution was 1.08 points (89% PI [0.71,1.45]) higher after 20 min in the conservatory compared to the mall. At 40 min, the difference was 0.90 points (89% PI [0.53,1.26]), and at 60 min, the difference was 0.91 points (89% PI [0.55,1.28]). 100% of MCMC chains showed a difference greater than 0 at all three time points.

Participants also reported feeling closer to people in their surroundings while in the conservatory compared to the mall at all three survey timepoints, Fig. 4b. On a 10-point scale, the posterior distribution was 1.15 points (89% PI [0.72,1.59]) higher after 20 min in the conservatory compared to the mall with 100% of MCMC chains showing a difference greater than 0. At 40 min, the difference was 0.93 points (89% PI [0.51,1.35]) with 100% of MCMC chains showing a difference greater than 0, and at 60 min, the difference was 0.51 points (89% PI [0.09,0.94]), with 97.4% of MCMC chains showing a difference greater than 0.

Feelings of closeness to friends and family showed an unexpected baseline difference, despite ratings taking place before going to the conditional locations (Fig. 4c). Therefore, we subtracted baseline scores in each condition. In this adjusted model, there was no evidence of an

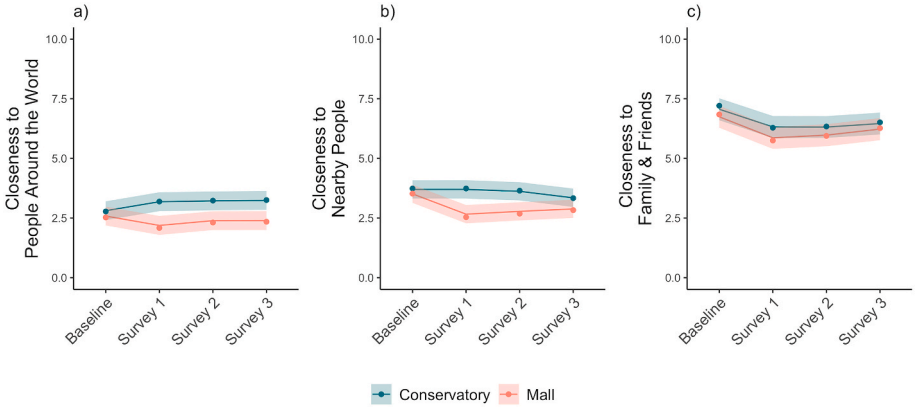

Fig. 4. Observed and modeled ratings for feelings of closeness to a) people around the world, b) people in the surroundings, and c) friends and family. Points are mean observed ratings from the raw data. The fitted line is the linear model's predicted estimate. The shaded area represents the 89th percentile interval of the posterior distribution.

interaction between conditions (20 min: difference = 0.14, 89% PI [−0.28, 0.57]; 40 min: difference = 0.02, 89% PI [−0.40, 0.43]; 60 min: difference = −0.09, 89% PI [−0.51, 0.33]). See Supplemental Table 3 for full regression models.

1.2.1.3. Feelings of connection to the social environment. Similar to the results for interpersonal thoughts and feelings, there was a condition by survey interaction for feelings of connection to the social environment (Fig. 5). Participants felt more connected to their social environment when walking in the nature conservatory. On a 10-point scale, the posterior distribution showed that connection to the social environment was 0.43 points higher (89% PI [0.00, 0.86]) in the conservatory compared to the mall after 20 min, with 94.5% of MCMC chains showing a difference greater than 0. At 40 min, connection was rated 0.60 points higher (89% PI [0.17, 1.02]) with 98.8% of MCMC chains showing a difference greater than 0. At 60 min, connection was rated 0.52 points higher (89% PI [0.10, 0.94]), with 97.5% of MCMC chains showing a difference greater than 0.

1.2.2. Environmentally oriented thoughts

1.2.2.1. Feelings of connection to the physical environment. Expanding beyond the social environment, the results showed that participants reported higher levels of connection to the physical environment in the conservatory compared to the mall at all three surveys (Fig. 6). On a 10-point scale, the posterior distribution showed that connection to the physical environment was 2.47 points higher (95% CI [1.93, 3.02]) in the conservatory compared to the mall after 20 min, 2.38 points higher (95% CI [1.82, 2.93]) at 40 min, and 2.35 points higher (95% CI [1.79, 2.91]) at 60 min. All MCMC chains showed a difference greater than 0 for all three interactions. See Supplemental Table 4 for full regression models.

1.2.2.2. Thoughts about the physical environment. The fourth response option to the question "Was [your most recent] thought mostly about yourself, mostly about others, about yourself and others, or not about people?" was "focused on things other than people." These non-social thoughts were more prevalent during walks in the conservatory compared to the mall at all survey time points (Fig. 3d). After ~20 min, (i.e., at Survey 1), the odds ratio between the two settings for these non-interpersonal thoughts was 2.12 (i.e., 2.12 times more likely to think about things other than people in the conservatory vs. the mall), 89% PI [1.24, 3.35], with 99% of the MCMC samples showing an odds ratio greater than one. The probability of non-interpersonal thoughts was 23% in the conservatory and 11% in the mall. At Survey 2, the probability of non-interpersonal thoughts was 21% in the conservatory and 14% in the mall. The odds ratio was 1.68 (89% PI [1.00, 2.59]), with 94.4% of the MCMC samples showing an odds ratio greater than one. At Survey 3, the probability of non-interpersonal thoughts was 15% in the conservatory and 7% in the mall, with an odds ratio of 2.26 (89% PI [1.20, 3.77]), and 98.4% of the MCMC samples showing an odds ratio greater than one. See Supplemental Table 2 for full regression models. Additionally, having thoughts about things other than people was correlated with feelings of connection to the physical environment while in the conservatory (rho = 0.21, 89% PI [0.02, 0.41]), but not while in the mall (rho = 0.01, 89% PI [-0.19, 0.22]).

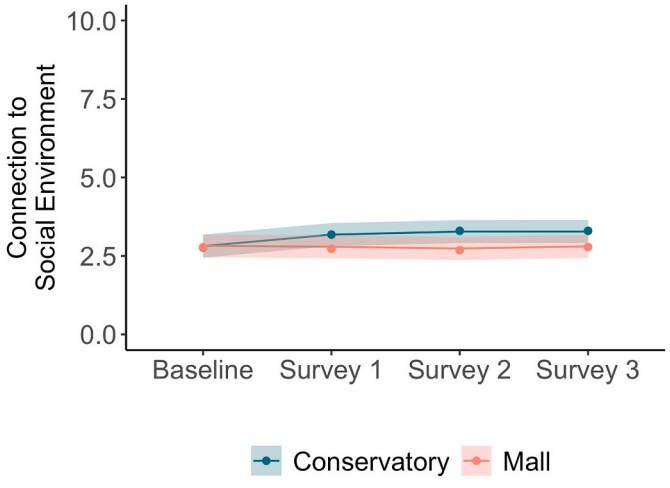

Fig. 5. Observed and modeled ratings for feelings of connection to the social environment. Points are mean observed ratings from the raw data. The fitted line is the linear model's predicted estimate. The shaded area represents the 89th percentile interval of the posterior distribution.

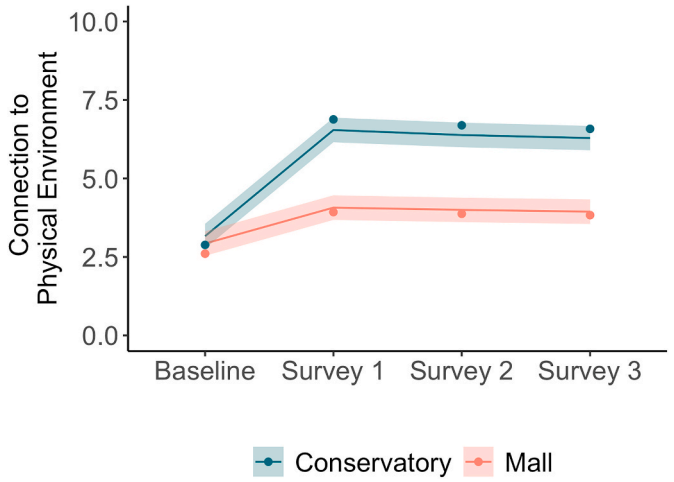

Fig. 6. Observed and modeled ratings for feelings of connection to the physical environment. Points are mean observed ratings from the raw data. The fitted line is the linear model's predicted estimate. The shaded area represents the 89th percentile interval of the posterior distribution.

1.4. Discussion

Across numerous measures we observed that being in a natural public space led to a greater emphasis on social and environmental thoughts and feelings compared to being in a retail environment. Participants were less likely to report self-focused thoughts in the conservatory and more likely to report thoughts about themselves in a relational sense (that is, themselves with other people). Participants reported feeling closer to people all over the world and people nearby, and more connected to their social environment when in the conservatory compared to the mall. They also felt more connected to physical elements of their environment and had more non-interpersonal thoughts (i.e., thoughts about things other than people) while walking in the conservatory. These effects were not explained by number of people in sight, although number of people around did interact with condition for some of the outcomes (see Supplementary Materials Appendix A).

2. Study 2

2.1. Materials & methods

2.1.1. Recruitment method

Participants were recruited via social media and listservs for seven 2-week study windows between May 31 and September 25, 2022. Our targeted N was between 400 and 500 participants based on budgetary constraints and the aim to collect data only during summer months. Specifically, geo-targeted Facebook advertisements were used to recruit participants from the Chicago area, the study was advertised on Reddit.

com on several Chicago-specific subreddits, and on Craigslist. An email was also shared with several Chicago-based community organizations to reach a larger sample of Chicagoans. Participants were instructed to email us if interested, and subsequently were given additional information and a pre-screening questionnaire to evaluate eligibility. Participants were eligible to participate in the study if they met the following criteria: a) Were 18 years or older, b) Lived in the Chicago city proper (zip code provided started with 606##), and c) Were not living in a Chicago Community Area where we already had a large number of participants (applicable starting in wave 4). Participants who met these criteria were sent instructions on how to enroll in a given study wave using the ExpiWell app. Not all participants who were sent enrollment details downloaded the ExpiWell app and completed the consent form or study procedures. Only those who completed the consent form and who provided non-fraudulent data (see QA section in Appendix B) on at least one of the surveys are included below.

2.1.2. Participant info

A total of 426 participants participated in the study procedures. Of these 426 participants, 9 participants were flagged as potentially providing partially fraudulent data. Participants were from 67 out of 77 Chicago community areas. The mean age was 35.96 years (SD = 12.29, Min = 18, Max = 73). One hundred four identified as male, 274 identified as female, and 13 identified as nonbinary or gender nonconforming. Sixty-four participants identified as Asian/Asian American, 105 as Black/African American, 58 as Hispanic/Latino/Chicano, 4 as Native American/Alaska Native, 2 as Native Hawaiian/Pacific Islander, 5 as Middle Eastern/North African, 183 as White/Caucasian, 6 as another racial or ethnic identity, and 2 preferred not to provide this information. Of the participants who responded to this question, 29 selected more than one ethnic or racial identity from this list. Some participants did not complete the study procedures required to link the background survey with the other surveys completed. There were 20 participants in Wave 1, 79 participants in Wave 2, 80 participants in Wave 3, 81 participants in Wave 4, 53 participants in Wave 5, 63 participants in Wave 6, and 59 participants in Wave 7.394 participants completed the baseline survey and 303 completed at least 1 park evaluation survey (average = 4.08 surveys per person, total park surveys = 1,235, unique parks = 443).

2.1.3. Study procedures

All study procedures were approved by the University of Chicago Institutional Review Board. Participants were instructed that some study elements were required, and others were optional. However, participants were paid based on the surveys they completed regardless of whether they did all the required surveys. Upon downloading the ExpiWell app, participants first provided informed consent. Though the study periods were each 2-weeks long, participants were able to download the app, provide informed consent, and enroll in the study up to 3 days before this two-week period. All participants were asked to complete a Background (Baseline) survey which took approximately 15–20 min and for which they were paid $25. The Background survey was listed as a "required" study component and was completed via Qualtrics and could be done as soon as they enrolled in the study (i.e., before the 2-week window started).

Once the 2-week period started, participants were asked to complete between 3 (minimum) and 5 (maximum) park surveys while in Chicago parks. These surveys were completed in the ExpiWell app. GPS was required to verify that participants were indeed in the location they specified (see QA checks section below for more details). Participants were paid $10 per park survey, which took approximately 5 min each.

To increase participation throughout the study window, participants were sent reminder messages via the Expiwell app mid-way through the 2-week period. These reminders included information on how many and which of the required surveys participants still needed to be completed and how many days they still had to complete these activities. After data quality checks were completed, participants were paid up to $135 in Amazon gift cards based on how many (valid) surveys were completed. Specific information on data quality checks can be found in Appendix B. Other study components (i.e., general outdoor surveys, RC-RAGE impulsive aggression task) were also conducted and are not reported on here. Details of all procedures can be found on the project OSF page (link).

2.1.4. Survey questions

2.1.4.1. Park survey. Participants were instructed "Please fill out the following survey while in a Chicago park. Each survey must be completed in a different park. Note that we will use GPS to verify your location inside a park to avoid fake responses. This survey should take approximately 5 min"

Participants first provided the name of the park they were visiting. They then rated perceived naturalness ("How natural is this park?") and connection to their environment ("How connected do you feel to other people around you?" and "How connected do you feel to the physical environment around you?"). All ratings were on a 7-point Likert scale. Participants were also asked to approximate the number of people in the park.

2.1.4.2. Background (baseline) survey. The background survey included general demographic and geographic questions (year of birth, gender, racial/ethnic identity, educational attainment, income, zip code, community area). A series of standardized questionnaires were included to evaluate: depressive and anxiety symptoms via the Patient Health Questionnaire-9 (PHQ-9) (Kroenke & Spitzer, 2002), trait impulsivity via the Barratt Impulsiveness Scale-11 (BIS-11) (Patton, Stanford, & Barratt, 1995), trait aggression via the Buss-Perry Aggression Questionnaire (BPAQ) (Buss & Perry, 1992), environmental sensitivity via the Highly Sensitive Persons Scale (HSP) (Aron & Aron, 1997), sense of belongingness via the General Belongingness Scale (Malone, Pillow, & Osman, 2012), life satisfaction via the Satisfaction with Life Scale (Diener, Emmons, Larsen, & Griffin, 1985), Big Five personality traits via the Big Five Inventory-2 Short Form (BFI–2S) (Soto & John, 2017), self-nature overlap via the Inclusion of Nature in Self scale (INS) (Schultz, 2002), tendencies towards rumination vs. reflection via the Rumination and Reflection Questionnaire (RRQ) (Trapnell & Campbell, 1999). Cronbach alphas for composite trait variables are reported in Supplemental Table B5; all were in the acceptable to good range. Analyses of trait variables are reported in Appendix B.

2.1.5. Statistical analysis

Statistical analyses were conducted in a Bayesian framework using multi-level models, with participant as a random/varying intercept. Connection to nearby people and the physical environment were modeled as continuous dependent variables with perceived naturalness as a continuous independent variable using linear regression. Alternative modeling choices (e.g., treating the dependent variable as an ordered categorical instead of continuous) were included as robustness checks and are reported in Supplementary Materials, Appendix B.

As in Study 1, regularizing priors were used for all models. Sensitivity analyses (see Appendix B) were conducted to confirm results were robust to chosen priors. Full specifications of the models, including their priors, are shown in Appendix B under "Linear Models." Each model was run with 10,000 draws and 1000 warmup draws for four Markov Chain Monte Carlo (MCMC) chains, for a total posterior distribution of 36,000 post-warmup draws. Posterior distributions were summarized by reporting the 89% percentile intervals (PI).

2.1.6. Transparency and openness

Data and analysis code are available at https://osf.io/t7qcw/. Models were run in R 4.2.2 (R Core Team, 2017) using the 'brms'

package (Bürkner, 2017). This study's analysis was pre-registered (https://osf.io/6uvmp). As noted above, additional dependent measures were collected during this study that are not reported here. Information about all variables and study activities available on the main "Mapping Chicago" OSF project page (https://osf.io/pjfcd/). All variables collected during the Baseline and Park surveys are reported in Supplementary Materials Appendix B.

2.2. Results

2.2.1. Relationship between naturalness and connection to nearby people

There was a positive relationship between the perceived naturalness of a park and the feelings of connection to nearby people while visiting, beta = 0.19 (89% PI [0.13, 0.25]), see Fig. 7. This relationship was robust to modeling choices, such as including park as an additional varying intercept (beta = 0.20, 89% PI [0.14, 0.27]), including varying slopes for participant (beta = 0.20, 89% PI [0.14, 0.27]), and treating connection as an ordered categorical instead of continuous variable (beta = 0.15, 89% PI [0.10, 0.20]) (See Appendix B for details on these additional models).

2.2.2. Relationship between naturalness and connection to the physical environment

There was a positive relationship between the perceived naturalness of a park and the feelings of connection to the physical environment while visiting, beta = 0.42 (89% PI [0.37, 0.47]), see Fig. 7. This relationship was robust to modeling choices, such as including park as an additional varying intercept (beta = 0.42, 89% PI [0.36, 0.47]), including varying slopes for participant (beta = 0.42, 89% PI [0.36, 0.49]), and treating connection as an ordered categorical instead of continuous variable (beta = 0.35, 89% PI [0.30, 0.40]) (See Appendix B for details).

2.4. Discussion

We found positive relationships between naturalness and feelings of connection to nearby people and the surrounding physical environment. Number of people in sight did not explain these relationships (see Supplementary Materials Appendix B). This suggests that naturalness may be a key component of public spaces that is associated with feelings of connection.

3. General discussion

Our results are in line with previous work showing that exposure to natural environments may increase orientation towards others (Goldy & Piff, 2020), but extend the work to include conscious thoughts and feelings. Broadly, these results suggest a pattern of thoughts and feelings while in a natural space that is less self-focused and instead more focused on, and connected to, both people and other things in the surrounding environment. Study 2 complemented the results of Study 1, focusing on connection to people nearby and the physical environment, by demonstrating that they generalize across a continuum of naturalness in public spaces and are seen in a more diverse group of participants. Within our Study 1 results, we can be most confident of the higher levels of connection to people around the world and connection to the physical environment in the nature conservatory, as the models showed all draws in the posterior distribution (i.e., all MCMC chains) being above zero at all timepoints for those metrics. The percentage of the posterior distribution that matches the direction (positive/negative) of the point estimate can be understood as the likelihood that the parameter is, in fact, in that direction. Thus, we are also very confident about the higher levels of connection to the social environment (96.7% positive MCMC chains) and closeness to nearby people (99.1% positive MCMC chains) in the conservatory, as well as more thoughts about the self (97.4% MCMC chain with odds ratios greater than one) in the mall. We have less confidence in the difference for thoughts about the self with others, as overall 87.9% of MCMC chains showed an odds ratio greater than one for the conservatory.

In Study 1, we did not define the term "social environment" for participants, which meant they were allowed to interpret what the construct meant for them. There were similar patterns of results for connection to the social environment and closeness to people nearby, as well as closeness to people around the world. The ratings on these questions all showed large, positive correlations as well, with connection to the social environment correlating more strongly with closeness to nearby people than people around the world. This may reflect participants using similar cues from their surroundings to answer these questions. In the present study, we were not able to test the validity of these measures, and future research should make efforts to do so. For instance, our sociality questions could be compared to the recently developed UBC State Social Connection Scale (Lok & Dunn, 2022).

By having participants report thought content repeatedly while in

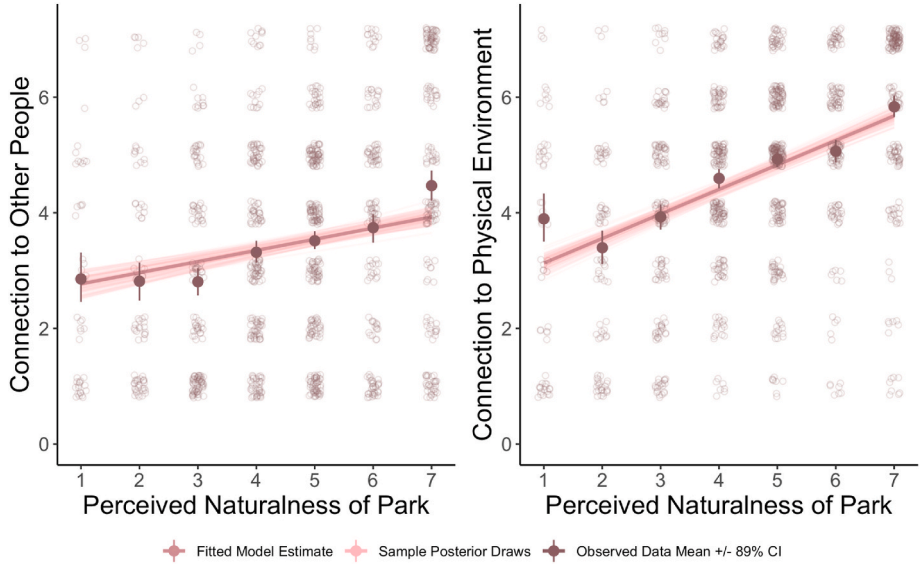

Fig. 7. Association between perceived naturalness and connection to other, nearby people (left) and the surrounding physical environment (right). Dark pink line is the fitted model prediction, light pink lines are sample posterior draws, open circles are raw data points, and filled circles are the mean of observed data at each naturalness level, with 89% CI. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

the two environments of Study 1, we were able to measure how differences in thoughts changed over time with increasing amounts of exposure. All observed differences were present at the first surveyed timepoint, indicating that spending approximately 20 min in these environments was sufficient to induce differences in thoughts and feelings. Additionally, all differences in thought content were present at all three time points, indicating the strong persistence of these effects. Findings like this indicate the value of collecting measurements *during* explorations of different environments.

It remains unknown how persistent thought content differences would be after participants left the respective environments. For example, at the end of the hour walk in the nature conservatory, participants were less likely to be thinking about themselves, but we do not know if this shift away from self-focused thinking would persist for another hour after leaving the conservatory. Doing so would require new studies that continue to monitor thoughts after participants leave different environments, which could be conducted using our ecological momentary assessment procedure. Additionally, given the causal impact of conscious thoughts on behavior (Baumeister, Masicampo, & Vohs, 2011), studies that examine social thinking with pro-social behavior, or environmentally focused thinking with pro-environmental behavior, could elucidate links between thought content and behavior in these domains. For instance, conscious feelings of connection to others may mediate the occurrence of pro-social behavior that has been observed after exposure to natural environments. Given that nature connectedness is associated with pro-environmental behaviors (Geng, Xu, Ye, Zhou, & Zhou, 2015), having access and opportunity to visit safe, urban greenspace may be helpful for environmental conservation efforts (Maurice, Prévot, Bessa-Gomes, & Baudry, 2021), which is of consequence given issues like climate change.

There are several limitations to the generalizability of Study 1. Study 1 was limited to two locations in one large US city. The design and amenities at conservatories and malls, as well as other natural and commercial spaces more broadly, around the world may influence thoughts about the social and physical environments. Results may also be influenced by cultural differences in the purposes of these public spaces. Our study locations were chosen in part because they were accessible year-round, similar in size, free to enter, desirable and frequently visited, and approximately equal distance from our lab. In addition to differing in their degree of naturalness, our two study locations differed on other factors, such as their neighborhood and demographics of visitors. It will be informative to replicate this study in additional locations, of both conservatories and malls but also other public spaces, to determine which results dimensions of spaces are important for the observed effects. We attempted to conduct the study in an ecologically valid manner by having participants visit the locations during normal operating hours throughout the week with other visitors present, while using mobile devices. One aspect that may be different from typical environmental exposure, however, is that participants visited these locations without companions. Visiting these locations with companions is likely to shape the thoughts individuals have about themselves and others.

Study 2 addresses some of the limitations of Study 1 by including a wide range of public parks in Chicago and showing that relationships between connection to others and the environment hold over a range of perceived naturalness. Additionally, park visits during Study 2 routinely took place simply as part of a participant's daily life – answers to a question about whether they visited the park to just fill out the survey or for other reasons included comments such as "having a walk with my niece", "I was walking by to run an errand", and "Was on my morning walk and decided to stop in," adding to the real-world validity of the findings.

In conclusion, this study further informs the immediate impact of our surrounding physical environment on conscious thoughts and feelings, through interactions with different public spaces that vary in naturalness. We present evidence that visiting natural public spaces, compared to less natural public spaces, seems to be beneficial for higher feelings of connection to other people as well as the environment around us. In an age where people increasingly feel disconnected from others (Konrath, 2013) and the natural world (Hartig & Kahn, 2016; Kesebir & Kesebir, 2017), visiting urban greenspace may counteract these feelings.

CRediT statement

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Data and materials availability

Data and code are available on OSF: https://osf.io/cu6jr/ (Study 1) and https://osf.io/t7qcw/ (Study 2).

Declaration of competing interest

The authors declare that they have no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2023.102046.

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