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Wasting the Restorative Potential: Influences of Plastic and Biowaste on Psychological Restoration After Real, Virtual, and Imagined Walks

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Abstract

Nature experiences benefit human wellbeing by, for example, increasing subjective restoration and positive affect while reducing negative affect. However, natural environments are threatened by several crises, including pollution. In three preregistered studies, one correlational and two experimental, we investigated the relationship between (plastic) litter and restoration after a walk. In Study 1, participants did a self-selected restorative walk and afterwards reported observed litter. In two experimental studies, we manipulated the presence of plastic waste, biowaste (which served as an active control condition with human-sourced but degradable litter), and no waste in a virtual (i.e., video; Study 2) and an imagined (Study 3) forest walk. In all studies, we assessed subjective restoration, current affect and connectedness to nature, attractiveness and preference of scenery, as well as plastic-related problem awareness, intentions, and policy support. Results showed that litter, especially from plastic, is associated with harmful changes in subjective restoration, affect, and the perception of the scenery. Connectedness to nature, as well as plastic-related problem awareness, intentions, and policy support were not affected by the presence of plastic. Thus, plastic pollution influences human wellbeing negatively, but did not affect factors important to reduce consumption. Therefore, more research on tackling the plastic crisis is needed.

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Keywords

natural environments, restoration, plastic pollution, litter, guided imagery

Non-Technical Summary

Background

Being outside in nature is beneficial for humans. Usually, they feel better, more relaxed, and more connected to nature. However, natural environments are polluted with plastic more than ever.

Why was this study done?

In three studies, we investigated whether plastic litter impacts wellbeing when taking a walk. Plastic litter and associated thoughts can, for example, induce negative feelings and decreased feelings of being away from everyday life. Thus, we expected lower wellbeing when the environment was littered.

What did the researchers do and find?

In the first study, we asked participants how they felt and then to make a restorative walk at their preferred location. Afterwards they reported again how they felt and whether they saw litter. In the second study, participants watched a video of a forest walk. The environment in the video was either litter-free, littered with plastic, or littered with food waste. The latter helped us to disentangle the effects of plastic from other human-sourced, but degradable elements introduced to the natural environment. Again, we asked, how they felt before and after watching the video. In the third study, we asked people to imagine taking a restorative forest walk. Again, the environment was either litter-free, contained plastic, or food waste. In all studies, people felt better and more connected to nature after making a restorative walk. However, their feelings were more negative and they felt less restored when plastic litter was present. Moreover, they liked the place less when plastic was in the scenery. We also studied, whether plastic waste influenced how aware people are about plastic pollution, whether they would reduce plastic in their grocery shopping, and whether they would support policy regulations to reduce plastic consumption and pollution. Perceiving plastic on a restorative walk did, however, not influence how people thought about plastic consumption and pollution. It did also not change how connected they feel to nature at that moment.

What do these findings mean?

Plastic litter in natural environments leads to lower wellbeing for people visiting that place for a restorative walk. At the same time, it seems not to influence factors that are important to reduce plastic consumption.

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Highlights

- Natural environments generally benefit wellbeing and nature connectedness.
- Plastic pollution has harmful effects on ecosystems, wildlife, and potentially human health.
- We investigated the effects of plastic pollution on wellbeing, connectedness, and variables related to action.
- Plastic pollution in natural environments negatively influenced restoration and current affect.
- Plastic pollution did not affect connectedness and predictors to reduce plastic consumption.

Modern everyday life brings many demands that deplete cognitive resources. To restore them, nature experiences can be helpful. Numerous studies showed that nature experiences have beneficial effects on humans' mental and physical health (for reviews, see Berto, 2014; Hartig et al., 2014; Kuo, 2015; Twohig-Bennett & Jones, 2018). However, natural environments are in danger: loss of biodiversity, consequences of climate change, and pollution are only few of several crises, which lead to substantial changes in the environment and thereby also to a threat for humans (e.g., Persson et al., 2022; Rockström et al., 2009; Steffen et al., 2015). Besides changes in species occurrence and abundance due to biodiversity and habitat loss, natural environments change by high introduction of litter. Plastic waste and its particles are – among others – major sources for pollution. Meanwhile plastic is found worldwide, even in the deep sea of the Antarctic and Arctic (e.g., Cunningham et al., 2020; Meyer et al., 2023; Shahul Hamid et al., 2018).

Plastic and pollution therewith are perceived as environmentally harming and negative (see Heidbreder et al., 2019, for a review; Menzel et al., 2021). Despite the growing awareness of this problem, the consumption of plastic and other materials that enter the environment is still extremely high (PlasticsEurope, 2020). The increasing plastic pollution is threatening ecosystems in various ways, for example by bioaccumulating in the food chain or hurting animals (Li et al., 2016; Persson et al., 2022). Additionally, it can affect human mental wellbeing, as littered environments were perceived of lower quality for mental restoration (Wyles et al., 2016). The current work investigated these effects on subjective restoration in more detail and tested whether experiences in a littered environment are associated with plastic-related problem awareness, intentions, and policy support.

Restorative Experiences

Restoration is defined as renewing resources that were depleted by stressors or everyday tasks (i.e., recovering certain states of mood and attention, but also physical condition; cf., Hartig, 2004, 2017). To restore depleted resources, nature experiences are helpful (e.g.,

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Kaplan, 1995; McMahan & Estes, 2015; Stevenson et al., 2018). Not only direct exposure to nature but also indirect exposure, such as virtual (Browning et al., 2021; Menzel & Reese, 2022; Reese et al., 2022) or imagined (Coughlan et al., 2022; Koivisto & Grassini, 2023) nature experiences, can lead to restoration. However, effects of such indirect exposures are often smaller than for direct ones (Browning, Mimnaugh, et al., 2020; Browning, Shipley, et al., 2020). Additionally, connectedness to nature (CTN), which is associated with both wellbeing and pro-environmental behaviour, can be increased by (direct and indirect) nature experiences (Coughlan et al., 2022; Mackay & Schmitt, 2019; Pritchard et al., 2020; Sheffield et al., 2022; Whitburn et al., 2020).

There are several (partly complementary) theories explaining restorative effects evoked by nature. First, the attention restoration theory proposes that attentional capacities, which are depleted by several daily tasks and generally more in urban environments, can be restored in nature, due to some restorative qualities that natural environments generally possess (Kaplan, 1995; Kaplan & Kaplan, 1989; see Ohly et al., 2016; and Stevenson et al., 2018, for related meta-analytic findings). For example, 'soft fascination' or feelings of 'being away' are assumed to be important for this cognitive restoration (Kaplan, 1995). Especially the latter might be limited in littered environments, because it reminds of human activity (cf., Wyles et al., 2016).

Second, the stress reduction theory suggests that nature exposure leads to the recovery from stress via positive affective states (PA), which often are the initial response to natural environments (Ulrich, 1983; Ulrich et al., 1991). Empirical findings generally support this theory (Kondo et al., 2018; McMahan & Estes, 2015; Menardo et al., 2021; Mygind et al., 2021). Compared to intact nature, littered environments might evoke a less positive response as (plastic) waste is generally associated with negative valence (e.g., Menzel et al., 2021; Wyles et al., 2016).

Third, the perceptual fluency account (Joye & van den Berg, 2011) proposes that natural stimuli are being processed more easily compared to urban stimuli due to certain visual properties. This easy – or fluent – processing is assumed to be accompanied by PA. Stress reduction and attentional restoration are proposed outcomes from the ease of processing (Joye & van den Berg, 2011). Hence, the perceptual fluency account suggests that restorative effects of and preference for nature are based on processing mechanisms. Although this theory has merit, empirical evidence is scarce (e.g., Menzel & Reese, 2021, 2022). As litter adds complexity and chaos (cf., Bielinis et al., 2022) to the scenery, it likely influences its lower-level processing, and therefore the theory implies lower restoration and preference for littered environments.

Fourth and in contrast to the other theories, Egner and colleagues (2020) proposed that nature's restorative effects are the result of learning processes (i.e., classical conditioning). Their conditioned restoration theory claims that modern humans' leisure time, which is often spent in nature, evokes beneficial effects, and experiencing these positive effects reliably in natural environments leads to the association of them with nature.

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Thus, nature becomes a conditioned stimulus and restoration a conditioned response (Egner et al., 2020). This conditioned stimulus can generalize over time so that other natural stimuli like virtual nature evoke restorative effects, too (Egner et al., 2020). Assumingly, the more an environment would differ from the conditioned stimulus (e.g., through littering), the lower the restoration evoked by it.

The presented theories aim at explaining restorative effects of nature. These theories have different approaches and viewpoints, but all give at least some indication that litter would limit restorative effects of nature. Besides the theories' specific assumptions and implications, a further argument hints at lower restoration in littered environments: The theories mentioned assume that nature needs to be safe to be restorative, but litter might reduce perceived safety, which would lead to a lower restorative potential of the environment. Furthermore, most of the described theories rely on a certain preference for a landscape to be restorative. Therefore, we also introduce theories explaining environmental preferences in the next section.

Environmental Preferences

Evolutionary theories assume that adaptive processes during human evolution directly explain current preferences, while cultural theories propose learning mechanisms. An example for the former is the savannah or habitat hypothesis (Orians, 1980; Orians & Heerwagen, 1992), which claims a preference for those environments that were abundant during early human evolution and aided survival. Examples for the latter include the topophilia hypothesis (Tuan, 1974), suggesting a preference for familiar environments, and Carlson's ecologic aesthetic hypothesis (Carlson, 2009), suggesting a preference for those environments that are perceived as ecologically precious and, thereby, stating that knowledge about ecological functions leads to preference. Following this latter hypothesis, a littered environment would be less precious and therefore less preferred. A similar conclusion can be drawn from the evolutionary theories, as our human ancestors lived in environments that were free of plastic and therefore respective pollution alters the environment in an unpreferred manner. In sum, theories on restorative experiences and environmental preferences predict that (plastic) litter would negatively influence restoration and preference.

Current Research

Previous research already indicated that littered environments were less preferred and perceived of lower restorative quality (Bielinis et al., 2022; Verlič et al., 2015; Wyles et al., 2016): for example, Wyles and colleagues (2016) asked participants to rate images of coastal environments. They found that littered beaches (esp. through items littered by the public) were preferred less and perceived to be of lower restorative quality than clean beaches. Furthermore, their additional qualitative data supported the quantitative

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data and further indicated negative emotions and perceived risks related to litter (Wyles et al., 2016). The study by Verlič and colleagues (2015) investigated characteristics of a natural trail on the perception of the trail and walking experience. Among other results, they found that present 'litter', 'vandalism', and 'lack of management' were perceived negatively and had negative impacts on subjective restoration. In another within-subjects experiment (Bielinis et al., 2022), participants viewed forest scenes with and without an open dump. Among others, the site with the dump was perceived as dirtier, less enjoyable, and less restorative. All these studies (Bielinis et al., 2022; Verlič et al., 2015; Wyles et al., 2016) focussed on the evaluation of the scenery (including restorative quality) instead of evoked affect and restoration. Furthermore, none of the studies investigated specific effects of plastic.

In the current work, we investigated the relationship between *plastic* pollution and mental restoration more specifically by conducting one correlational and two experimental studies with real, virtual, and imagined walks. We not only assessed the perception of the littered scenery, but also its influence on subjective restoration and affect in a pre-post design (and for the experimental studies also with control conditions). Furthermore, we also tested effects on current CTN, plastic-related problem awareness, intentions, and policy support, as these are important to tackle plastic pollution. Most importantly, we included in our experimental studies not only a control group without litter but also one with human-sourced but degradable bio-waste to investigate the specific impact of plastic pollution. We expected that littered – especially through plastic – compared to clean environments were preferred less, led to less subjective restoration, and a smaller increase in PA and CTN, as well as a smaller decrease in negative affect (NA). For the plastic-related outcomes both directions are reasonable as the presence of plastic might increase problem awareness, but the assumed decrease in CTN and PA might lead to less pro-environmental action (cf., Whitburn et al., 2020; Zawadzki et al., 2020).

In all presented studies, we recruited German-speaking convenience samples. This approach was chosen as the studies were student projects with limited time and financial resources. Our recruiting strategies were made explicit and critically considered in the Discussion. All questionnaires were implemented online using SoSciSurvey (Leiner, 2021). All studies were preregistered (see below for respective links) and all deviations thereof were made explicit. All analysis decisions were made before data collection if not stated otherwise. Materials, data, and analyses can be found at Menzel, Wissel et al. (2023). Data were analysed with R (R Core Team, 2020; version 4.0.3).

Study 1

In our first preregistered study (Menzel & Wissel, 2022), we investigated the relationship between litter and restoration by asking participants to take a restorative walk at their preferred place. We expected negative relations between litter seen and attractiveness

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and preference of the scenery, subjective restoration, increase in PA and current CTN, and decrease in NA. Furthermore, we studied the relationship of litter and plastic-related problem awareness, intention, and policy support. As participants were asked to take a walk at their desired location, ecological validity is high. We focussed on restorative environments instead of natural environments in particular, because we were interested in restoration effects and left it to participants to decide what is most restorative to them. Furthermore, giving participants the restraint of natural environments would make it more difficult for them to take the walk at the desired length at all. Nevertheless, we assessed the perceived naturalness of the environment.

Method

Participants

For analyses, we aimed at a final sample of 125 (see Menzel, von der Heiden et al., 2023, S1 and S2 for further information). On our questionnaire, we registered 1321 clicks, 302 questionnaires were started, and 146 questionnaires were completed. After completion, seven participants refused data processing. Of the remaining 139 participants, further participants were excluded, because they did not walk (n = 4), their walk was shorter than 20 minutes (n = 8) or longer than 40 minutes (n = 15), they failed the attention check (n = 3), stated to not have participated seriously (n = 1), or finished the questionnaire at a different location (n = 3). The final sample consisted of 105 participants (M_{age} = 28.77, SD_{age} = 11.63, Min_{age} = 19, Max_{age} = 67; female: 72, male: 31, diverse: 2; see Menzel, von der Heiden et al., 2023, S3 for further information).

Design and General Procedure

In this correlational study, participants were invited to take a walk in the scope of our survey. After giving informed consent, participants were asked to rate their current CTN and affect. Then, we instructed them to take a restorative walk of approximately 30 minutes that they should do alone, without using electronic devices, and in daylight. After the self-paced walk, participants were again asked to state their current CTN and affect, followed by their subjective restoration. That was continued by questions about their walk, including whether and how much waste they saw, and questions on plastic-related problem awareness, intentions, and policy support. The questionnaire ended with control questions and assessment of sociodemographic data.

Materials

Connectedness to Nature — We assessed current CTN with an adapted version of the Connectedness to Nature State Scale (CTN-s; Mayer et al., 2009), which is based on Mayer and Frantz (2004). We excluded the item "When I think of humans' place on earth right now, I consider them to be the most valuable species in nature" and included

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a state version of the item "My personal welfare is independent of the welfare of the natural world." from the original scale (Mayer & Frantz, 2004). We adapted a German translation of the trait scale (Cervinka et al., 2012) to the current state. Thus, CTN-s was measured with 13 items (e.g., "Right now I'm feeling a sense of oneness with the natural world around me"), for which participants stated their agreement on a 5-point-scale from "strongly disagree" to "strongly agree". Cronbach's α for all measures can be found in Table 1.

Table 1

Cronbach's Alpha, Mean, and Standard Deviation for Outcome Variables in Study 1

Outcome variable	Cronbach's α	*M*	*SD*
Waste	–	2.40	1.11
Naturalness	–	59.95	27.08
ROS	.88	5.07	1.11
PA pre	.89	2.63	0.73
PA post	.92	3.09***	0.83
PA diff	–	0.46	0.59
NA pre	.89	1.63	0.67
NA post	.94	1.43***	0.64
NA diff	–	-0.21	0.36
CTN-s pre	.91	3.09	0.85
CTN-s post	.93	3.54***	0.88
CTN-s diff	–	0.46	0.50
Attractiveness of scenery	–	3.64	0.95
Preference of scenery	–	3.90	0.85
Problem awareness	.83	4.26	0.60
Intention	.73	3.25	1.01
Policy support	.92	6.09	1.00

Note. ROS = restoration outcome scale. PA pre = positive affect before walk. PA post = positive affect after walk. PA diff = difference score between PA pre and PA post. NA pre = negative affect before walk. NA post = negative affect after walk. NA diff = difference score between NA pre and NA post. CTN-s pre = connectedness to nature state before walk. CTN-s post = connectedness to nature state after walk. CTN-s diff = difference score between CTN-s pre and CTN-s post.
***$p < .001$ (pre-post comparison).

Affect — PA and NA were measured with a German version of the Positive Affect and Negative Affect Schedule (PANAS; Breyer & Bluemke, 2016; Watson et al., 1988). Participants were asked to state how much they currently experience ten positive (e.g., "excited") and ten negative (e.g., "afraid") feelings (5-point-scale from "not at all" to "extremely").

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Restoration — Restoration was measured with a German translation of the restoration outcome scale (ROS; Korpela et al., 2008) that was adapted to our intervention (i.e., "After the walk, …"). Participants were asked to rate on six items (e.g., "The walk helped me to feel restored and relaxed.") how they felt (7-point-scale from "not at all" to "totally").

Waste Recognition — First, we asked participants whether there was something special on their walk and screened their open responses for waste-related words. Second, we asked them directly how much they recognized waste on their walk from "not at all" to "very much" on a 5-point-scale. If they did not check "not at all" they were asked to specify the waste (e.g., plastic, paper; multiple answers possible).

Characteristics of the Walk — When assessing walk characteristics that were important for applying our exclusion criteria (e.g., whether they actually did a walk), we explicitly mentioned that participants' incentive is unaffected by their response and asked them to be honest. We asked whether they truly did the walk, how long it was, and whether they finished the questionnaire at the same place where they started them. For exploratory reasons, we also asked how their walk environment was characterized (e.g., forest, rural area, human-made noise; multiple responses possible), and how natural they perceived it (on a sliding scale from "not natural at all" to "very natural"). To assess preference and attractiveness of the scenery, we asked them to state their agreement on "I like the scenery of my walk environment" and "The scenery of my walk environment was attractive" (5-point scale from "completely disagree" to "completely agree"). The last two items based on a similar assessment used by White et al. (2010).

Problem Awareness — To assess problem awareness related to plastic, we used a scale by Heidbreder et al. (2020). For eight items (e.g., "plastic pollution in the soil") we asked how problematic they perceive it (5-point-scale from "no problem" to "very big problem").

Intentions to Use Plastic — We used an adapted scale based on Heidbreder et al. (2023) to assess intentions to use plastic. For three items (e.g., "When thinking about my next grocery shopping, I will not buy fruits/vegetable that is packed in plastic."), they were asked how much they agree with the statement (5-point scale from "strongly disagree" to "strongly agree").

Policy Support — We created a scale that assessed support of 10 policy measures related to plastic (e.g., "Ban on disposable plastic cutlery."). All items can be found in Menzel, von der Heiden et al., 2023, S4. Participants stated their support on a 7-point scale from "strongly oppose" to "strongly support".

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Results

The average walk was 31 minutes (*SD* = 5 min 9 sec) and was characterized by slightly above medium naturalness (*M* = 59.95, *SD* = 27.08; see also Menzel, von der Heiden et al., 2023, S5). Only two participants mentioned waste spontaneously. When asked directly, 22 participants reported to have seen no waste, while 83 saw at least some; 58 of them reported to have seen plastic (see Menzel, von der Heiden et al., 2023, S6 for more information). When comparing participants who saw no waste to those who saw waste, we found significant higher perceived attractiveness and preference of the scenery (Menzel, von der Heiden et al., 2023, S7). Descriptive statistics of all measures can be found in Table 1, and see also Menzel, von der Heiden et al., 2023, S7 for the comparison of subgroups.

PA was higher after the walk than before, $t(104) = -9.97$, $p < .001$, $d = -0.58$, 95% CI [-0.573, -0.345]. NA was lower after the walk than before, $t(104) = 5.91$, $p < .001$, $d = -0.31$, 95% CI [0.137, 0.275]. CTN-s was higher after the walk than before, $t(104) = -9.45$, $p < .001$, $d = -0.53$, 95% CI [-0.555, -0.362].

For each dependent variable, we run a multiple regression. When outliers were identified for a given regression (see Menzel, von der Heiden et al., 2023, S9 for more details), models excluding these outliers were reported (Table 2). Additional to these preregistered models, we calculated exploratory bivariate correlations (Menzel, von der Heiden et al., 2023, S8), regressions including age and gender (Menzel, von der Heiden et al., 2023, S10), and regression models with ROS, as well as difference scores of PA, NA, and CTN-s to predict plastic-related problem awareness, intentions, and policy support (Menzel, von der Heiden et al., 2023, S11).

Table 2

Multiple Regression Results for Study 1

Model	B	*SE* B	95% CI	β	*p*
ROS ($n = 104$, $R^2_{adj} = .38$, $p < .001$)					
Constant	4.44	0.48	[3.488, 5.393]		< .001
PA pre	0.28	0.12	[0.047, 0.516]	0.20	.019
NA pre	-0.64	0.13	[-0.894, -0.391]	-0.42	< .001
CTN-s pre	0.34	0.10	[0.136, 0.548]	0.27	.001
waste	-0.04	0.08	[-0.187, 0.114]	-0.04	.631
PA post ($n = 105$, $R^2_{adj} = .53$, $p < .001$)					
Constant	0.91	0.32	[0.267, 1.556]		.006
PA pre	0.77	0.08	[0.613, 0.933]	0.68	< .001
NA pre	-0.03	0.09	[-0.204, 0.140]	-0.03	.713
CTN-s pre	0.13	0.07	[-0.006, 0.271]	0.14	.060
waste	-0.09	0.05	[-0.191, 0.014]	-0.12	.090

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Model	B	*SE* B	95% CI	β	*p*
NA post[a] (n = 103, R^2_{adj} = .74, p < .001)					
Constant	0.14	0.16	[-0.230, 0.456]		.372
PA pre	-0.02	0.04	[-0.101, 0.049]	-0.03	.637
NA pre	0.77	0.05	[0.640, 0.917]	0.85	< .001
CTN-s pre	-0.002	0.034	[-0.075, 0.074]	-0.002	.965
waste	0.03	0.03	[-0.031, 0.104]	0.06	.257
CTN-s post[a] (n = 105, R^2_{adj} = .69, p < .001)					
Constant	1.09	0.28	[0.466, 1.767]		< .001
PA pre	-0.03	0.07	[-0.182, 0.132]	-0.02	.679
NA pre	-0.06	0.08	[-0.224, 0.086]	-0.05	.408
CTN-s pre	0.87	0.06	[0.718, 0.985]	0.84	< .001
waste	-0.02	0.04	[-0.108, 0.081]	-0.02	.697
Attractiveness of the scenery (n = 105, R^2_{adj} = .10, p = .006)					
Constant	3.49	0.52	[2.465, 4.524]		< .001
PA pre	0.22	0.13	[-0.032, 0.481]	0.17	.085
NA pre	-0.20	0.14	[-0.478, 0.072]	-0.14	.146
CTN-s pre	0.11	0.11	[-0.113, 0.328]	0.10	.337
waste	-0.19	0.08	[-0.350, -0.022]	-0.22	.027
Preference of the scenery (n = 105, R^2_{adj} = .08, p = .013)					
Constant	3.76	0.47	[2.832, 4.694]		< .001
PA pre	0.17	0.12	[-0.064, 0.399]	0.14	.155
NA pre	-0.15	0.13	[-0.401, 0.096]	-0.12	.227
CTN-s pre	0.11	0.10	[-0.086, 0.313]	0.11	.261
waste	-0.17	0.07	[-0.319, -0.023]	-0.22	.024
Problem awareness (n = 104, R^2_{adj} = .11, p = .004)					
Constant	4.46	0.31	[3.849, 5.084]		< .001
PA pre	-0.17	0.08	[-0.330, -0.019]	-0.22	.028
NA pre	-0.21	0.08	[-0.371, -0.045]	-0.25	.013
CTN-s pre	0.17	0.07	[0.039, 0.300]	0.26	.011
waste	0.04	0.05	[-0.057, 0.137]	0.08	.413
Intentions (n = 105, R^2_{adj} = .06, p = .036)					
Constant	1.96	0.56	[0.845, 3.076]		< .001
PA pre	0.03	0.14	[-0.250, 0.306]	0.02	.842
NA pre	.01	0.15	[-0.289, 0.307]	0.01	.952
CTN-s pre	0.35	0.12	[0.113, 0.591]	0.30	.004
waste	0.05	0.09	[-0.129, 0.226]	0.05	.590

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Model	B	*SE* B	95% CI	β	*p*
Policy support (n = 103, R^2_{adj} = .10, p = .006)					
Constant	7.19	0.41	[6.372, 8.008]		< .001
PA pre	-0.37	0.11	[-0.580, -0.164]	-0.35	< .001
NA pre	-0.23	0.11	[-0.455, -0.004]	-0.19	.049
CTN-s pre	0.09	0.09	[-0.087, 0.263]	0.10	.321
waste	0.03	0.07	[-0.097, 0.165]	0.05	.609

Notes. β = standardized beta.
[a]bootstrapped confidence intervals.

Discussion

We instructed participants to walk in an environment that usually is restorative to them. As expected, the walk increased participants' PA and CTN-s, and decreased their NA. We tested whether litter influenced participants' subjective restoration, difference in PA, NA, and CTN-s, as well as their perceived attractiveness and preference of the scenery. Noteworthy, participants were not instructed to be aware of litter, which might explain why only few spontaneously reported to have seen some. However, when asked directly, the majority stated to have seen litter, esp. from plastic. Attractiveness and preference of the scenery was lower for those participants who saw litter than those who saw no litter. Similarly, waste intensity predicted attractiveness and preference in the regressions (noteworthy, when further controlled for age and gender these effects became only marginally significant; Menzel, von der Heiden et al., 2023, S10). Affect (but note the tendency for PA), restoration, CTN, as well as plastic-related problem awareness, intentions, and policy support were not predicted by waste.

Study 2

Because of the correlational nature of Study 1 (to keep high ecological validity), litter occurrence could not be controlled. Here, we investigated the relationship of litter and restoration experimentally in a highly-controlled between-subjects design. Thereby, we disentangled effects of human-sourced items in natural environments from plastic waste in particular by including a bio-waste condition. All three conditions – no waste, bio-waste, and plastic waste – were implemented similarly using a virtual walk (i.e., video; Figure 1A-C) and the latter two conditions included the same number and similar visual characteristics of items (Figure 1D). We expected highest restoration, PA, CTN-s, attractiveness and preference of scenery, and lowest NA for the no waste condition. We assumed lowest restoration, PA, CTN-s, preference and attractiveness of scenery, and highest NA for the plastic condition. Additionally, we asked whether problem awareness, intentions to reduce plastic, and policy support differ across conditions. We had no

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directed hypotheses for these variables as, on the one hand, presence of litter might increase problem awareness and then intentions to reduce plastic and an increase in policy support, or, on the other hand, decrease intentions and policy support due to potentially decreased nature connectedness (cf., Mackay & Schmitt, 2019; Whitburn et al., 2020).

Figure 1

Stimulus Material for Study 2

Note. A-C are screenshots from the videos in the no waste (A), bio-waste (B), and plastic waste (C) condition recorded in a German forest. D shows the 14 pairs of plastic (left) and bio-waste (right) items that were similarly distributed across the scenery (B, C). Loose bio-waste items were placed without the container that is visible in D.

The study was preregistered (see Menzel & von der Heiden, 2022). Deviating from our preregistration we added one further exclusion criterion to only include participants who could view the video in its original size (i.e., used a device with a screen larger than 12 inches). Noteworthy, we conducted a pilot study within a students' course, which was also preregistered (see Menzel et al., 2021). However, as we could not recruit

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the preregistered sample size and recognized flaws in the stimuli, this dataset was not considered further.

Method

Participants

For analyses, we aimed at a final sample of 156 (see Menzel, von der Heiden et al., 2023, S12 and S13 for further information). On our questionnaire, we registered 849 clicks, 297 questionnaires were started, and 191 were completed. After completion, two participants refused data processing. Further participants were excluded based on our criteria: insufficient screen size (n = 16), reporting to not attentively have watched the video in full length (n = 15), reported serious technical problems (n = 1), stated to not have completed the questionnaire seriously (n = 3), gave reason for inattentiveness (n = 6), reported waste in the no waste condition (n = 4), reported other waste than bio-waste (n = 20)[1] or no waste (n = 12) in the bio-waste condition, or reported only non-plastic waste (n = 3)[2] or no waste (n = 7) in the plastic condition. Nobody was excluded for being extremely fast or slow. The characteristics of the final sample (N = 102) are represented in Table 3 and Menzel, von der Heiden et al., 2023, S14. Age did not differ between groups, $F(2, 99) = 2.34$, $p = .101$, $\eta^2 = .05$. Similarly, gender distribution did not differ between groups, $p = .639$.

Table 3

(Sub-)Sample Characteristics for Study 2

Characteristic	Full Sample	No Waste	Bio-waste	Plastic Waste
***n* total**	102	42	18	42
Gender				
n female	74	28	14	32
n male	28	14	4	10
Age				
M	28.77	30.40	30.72	26.31
SD	9.76	11.46	9.80	7.27
range	18–75	20–75	20–54	18–58

1) We excluded all participants who stated to have seen waste that was not bio-waste, because the bio-waste condition served as a control condition including only 'natural' (i.e., compostable) items that were human-caused. Thus, the perception of any non-bio-waste was considered inappropriate for this control condition.

2) Participants were not excluded if they stated other waste *additionally* to plastic.

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Design and General Procedure

When advertising the study, we asked to conduct the study in a quiet and undisturbed place, and on a device with a screen larger than 12 inches and functioning audio. After giving informed consent, participants indicated their current CTN, PA, and NA. Then, we introduced them to the video. We asked to watch the video attentively and to transport themselves into the scenery. Participants were randomly assigned to one of three videos: no waste, bio-waste, plastic waste. After the video, they stated their current CTN, PA, and NA again, before indicating their perceived restoration. Then they stated how attractive and preferred the scenery was, and how likely they would visit such a scenery for a restorative walk. This was followed by attention and manipulation checks, and the plastic-related scales on problem awareness, intentions, and policy support. The questionnaire ended with control items and sociodemographic data.

Materials

As in Study 1, we assessed ROS, PA, NA, CTN-s, attractiveness of scenery, preference of scenery, problem awareness, intentions to use plastic, and policy support (see Table 4 for their Cronbach's α). Additionally, we assessed also how likely participants would visit a scenery similar to the represented one for a restorative walk on a 5-point scale from "not at all" to "totally" (cf., White et al., 2010)[3]. As an attention check, we asked participants what was shown in the video by using at least five words. Then, we asked whether and what kind of waste they saw (open response field with option to click "I have seen no waste").

Videos

We recorded three 4:36 min videos representing a forest walk (see Menzel, von der Heiden et al., 2023, S15 for more information). In the no waste condition, no waste was visible. In the plastic and bio-waste condition, 14 items (or piles) of plastic or bio-waste were part of the scenery (Figure 1). As a control, we asked whether they watched the video attentively until the end, whether they were at a device with a screen larger than 12 inches, and whether they experienced technical problems.

Results

Descriptive and ANOVA results of group comparisons, as well as indications for pre-post effects are displayed in Table 4. Explorative correlations among measures can be found in Menzel, von der Heiden et al., 2023, S16.

3) Deviating from preregistration, we analysed attractiveness, preference, and likelihood to visit such a scenery separately to allow a comparison to Study 1.

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Table 4

Cronbach's Alpha, Mean, Standard Deviation, and One-Way Analyses of Variance for All Variables in Study 2

	Full Sample			No Waste		Bio-waste		Plastic Waste				
Variable	**α**	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***F*(2, 99)**	***p***	**η^2**
ROS	.92	4.04	1.44	4.43	1.24	3.90	1.59	3.71	1.49	2.89	.060	.06
PA pre	.88	2.65	0.67	2.64	0.72	2.81	0.52	2.60	0.69	—	—	—
PA post	.89	2.63	0.72	2.67	0.74	2.70	0.57	2.56	0.78	—	—	—
PA diff	—	-0.03	0.44	0.03	0.45	-0.11	0.36	-0.04	0.46	0.65	.524	.01
NA pre	.86	1.52	0.57	1.52	0.55	1.44	0.68	1.55	0.56	—	—	—
NA post	.87	1.47	0.60	1.27***	0.34	1.51	0.62	1.65	0.73	—	—	—
NA diff	—	-0.05	0.64	-0.25_{a}	0.47	0.06_{ab}	0.61	0.11_{b}	0.76	3.74	.027	.07
CTN-s pre	.91	3.20	0.80	3.14	0.77	3.33	0.86	3.20	0.83	—	—	—
CTN-s post	.93	3.46***	0.83	3.36***	0.84	3.63*	0.64	3.49**	0.89	—	—	—
CTN-s diff	—	0.26	0.53	0.22	0.40	0.29	0.52	0.29	0.64	0.23	.796	< .01
Attractiveness of scenery	—	3.48	1.17	4.05_{a}	0.99	3.44_{ab}	1.38	2.93_{b}	0.97	11.73	< .001	.19
Preference of scenery	—	3.79	1.15	4.26_{a}	0.91	3.72_{ab}	1.32	3.36_{b}	1.12	7.42	.001	.13
Likelihood of visiting such a scenery	—	4.11	1.00	4.33	0.85	4.11	1.13	3.88	1.06	2.18	.118	.04
Problem awareness	.79	4.32	0.52	4.33	0.50	4.44	0.67	4.26	0.47	0.72	.488	.01
Intention	.66	3.41	0.90	3.34	0.77	3.56	1.28	3.40	0.84	0.23[a]	.791	-.02[b]
Policy support	.88	5.97	0.88	5.92	0.87	6.32	0.65	5.88	0.96	1.70	.187	.03

Note. ROS = restoration outcome scale. PA pre = positive affect before video. PA post = positive affect after video. PA diff = difference score between PA pre and PA post. NA pre = negative affect before video. NA post = negative affect after video. NA diff = difference score between NA pre and NA post. CTN-s pre = connectedness to nature state before video. CTN-s post = connectedness to nature state after video. CTN-s diff = difference score between CTN-s pre and CTN-s post. Means with different subscripts differ at the $p = .05$ level by Tukey's HSD post-hoc tests in the group comparison.
[a]Welch's $F(2, 41.50)$. [b]estimated ω^2.
*$p < .05$. **$p < .01$. ***$p < .001$. (Pre-post comparisons).

Pre-Post Comparisons

For PA, pre-post differences were not significant (full sample: $t(101) = 0.59$, $p = .560$, $d = 0.04$; no waste: $t(41) = -0.38$, $p = .709$, $d = -0.04$; bio-waste: $t(17) = 1.31$, $p = .209$, $d = 0.20$; plastic waste: $t(41) = 0.57$, $p = .573$, $d = 0.05$). NA decreased from pre to post in the no waste group, $t(41) = 3.47$, $p = .001$, $d = 0.51$, 95% CI [0.104, 0.396], but not in the other samples (full sample: $t(101) = 0.75$, $p = .453$, $d = 0.08$; bio-waste: $t(17) = -0.43$, $p = .674$, $d = -0.09$; plastic waste: $t(41) = -91$, $p = .366$, $d = -0.16$). CTN-s increased in all samples between pre and post measurement (full sample: $t(101) = -5.08$, $p < .001$, $d = -0.32$, 95% CI [-0.451, -0.194]; no waste: $t(41) = -3.62$, $p < .001$, $d = -0.27$, 95% CI [-0.345, -0.098]; bio-waste: $t(17) = -2.40$, $p = .028$, $d = -0.36$, 95% CI [-0.554, -0.036]; plastic waste: $t(41) = -2.98$, $p = .005$, $d = -0.34$, 95% CI [-0.492, -0.095]).

Group Comparisons

Restoration and change in PA differed not between groups (Table 4). However, change in NA differed. The decrease of NA was larger in the no waste compared to the plastic waste condition, $p = .028$, 95% CI [0.032, 0.683], while bio-waste did not differ from no waste, $p = .188$, and plastic waste, $p = .963$. The increase in CTN-s was similar for all groups. Attractiveness of the scenery differed, with the no waste condition being more attractive than plastic waste, $p < .001$, 95% CI [-1.669, -0.569], while bio-waste did not differ from no waste, $p = .113$, and plastic waste, $p = .200$. Preference of scenery differed, with the no waste condition being more preferred than plastic, $p < .001$, 95% CI [-1.465, -0.344], while bio-waste did not differ from no waste, $p = .183$, and plastic waste, $p = .456$. Likelihood of visiting a similar scenery for a restorative walk was similar across conditions. Problem awareness, intentions, and policy support did not differ between groups.

Discussion

In an experimental setting with a virtual forest walk, we investigated the role of plastic waste on subjective restoration, affect, CTN-s, attractiveness and preference of the scenery. As expected, the virtual walk through a litter-free forest led to an increase in CTN-s and a decrease in NA. However, unexpectedly, PA did not increase after the virtual walk. CTN-s increased similarly in all conditions. NA decreased only in the no waste condition and the change in NA differed between the no waste and plastic condition. In fact, in the no waste condition difference in NA was negative while it was positive in the plastic condition (i.e., NA increased; Table 4). Unexpectedly, group differences in PA and CTN-s were not significant, and we found only a tendency ($p = .060$) for our expected difference in subjective restoration. Nevertheless, similar to Study 1, perceived attractiveness and preference of the scene are influenced by the presence of waste: clean environments were rated more positively than those littered with plastic. Interestingly, the likelihood of visiting such a scenery was not influenced by that. Furthermore, problem awareness,

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intentions, and policy support were not affected by waste in our stimuli, although subjective restoration and intention to reduce plastic correlated positively in the full sample and the plastic waste group (Menzel, von der Heiden et al., 2023, S16).

The bio-waste condition did not significantly differ from both other conditions and its descriptive data indicates intermediate outcomes. These intermediate results indicate that human-sourced but degradable items may also influence the perception of the scenery and NA, but to a lesser extent. Thus, our results thereby also indicate that the effects found for plastic were partly rather specific to plastic as the same amount of bio-waste did not lead to such strong effects. This is not in line with implications drawn by theories on restoration (esp. attention restoration theory and perceptual fluency account) which would predict similar effects for human-sourced litter, irrespective of material. The specificity of litter type should be studied further to disentangle these effects more clearly.

Several participants commented the perceived low quality of the video and sound. This might explain the unchanged PA after watching the video. Although, our stimuli were well-controlled, our limited equipment could not produce high quality videos, which are highly abundant nowadays (e.g., professional movies) and to which participants might have compared our videos. Another limitation was the very high number of excluded participants, especially in the bio-waste condition, which was partly caused by participants' misinterpretation of items. This may be due to the items' small size within the video, and/or certain expectations about a littered environment (e.g., when seeing any litter, it is expected that plastic is among it). Noteworthy, our stimuli may also not have been universally restorative as it represents a particular German forest scenery in autumn. Therefore, in Study 3, we applied a design with an imagined forest to allow individual adaptations and to address some limitations related to the video stimulus (esp. video quality).

Study 3

As a replication for Study 2, we used a different approach, namely guided imagery. Furthermore, in contrast to the videos, in which we predetermined the appearance of the forest whether it was perceived restorative to a given participant or not, participants of Study 3 could individualize their restorative experience, while we still could manipulate litter presence. In Study 3, which was also preregistered (see Menzel & Tretau, 2022), we used the same design as in Study 2. Thereby, we manipulated three instances of litter in a guided imagery. Furthermore, we run our analyses for two subsamples: the full sample based on the assigned condition and a subsample based on whether and what litter was imagined. Generally, our hypotheses were similar as for Study 2.

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Method

Participants

For analyses, we aimed at a final sample of 246 (see Menzel, von der Heiden et al., 2023, S17 and S18 for further information). On our questionnaire, we registered 1142 clicks, 509 questionnaires were started and 308 completed. After completion, 14 participants refused data processing. Further participants were excluded based on our exclusion criteria: being under 18 years old (n = 1), did not complete the questionnaire seriously (n = 8), did not listen to the audio seriously until the end (n = 14), answered the attention item incorrectly (n = 23), indicated disinterest in open response field (n = 1), and had a relative speed index > 2.0 (n = 9) (Leiner, 2019). Although seven participants indicated technical problems, none of their open comments indicated a serious reason for exclusion; thus, all remained. The characteristics of the final sample (N = 238) are represented in Table 5 and Menzel, von der Heiden et al., 2023, S19. Age did not differ between groups, $F(2, 235) = 1.20$, $p = .304$, $\eta^2 = .01$. Similarly, gender distribution did not differ between groups, $p = .741$.

Table 5

(Sub-)Sample Characteristics for Study 3

Characteristic	No Waste	Bio-waste	Plastic Waste	Full Sample
***n* total**	81	81	76	238
Gender				
n female	60	57	52	169
n male	21	24	24	69
Age				
M	32.96	33.68	30.07	32.28
SD	16.98	16.24	12.52	15.44
range	18–80	18–77	18–74	18–80

Design and General Procedure

Design and procedure were similar to Study 2. We instructed participants to complete the questionnaire in a quiet setting and recommended headphones when listening to the guided imagery. After giving informed consent, we assessed CTN-s and affect. Then participants were asked to listen to their provided audio, which belonged to one of three conditions: no waste, bio-waste, or plastic waste (see below and Menzel, von der Heiden et al., 2023, S20). After the audio, they were again asked to state their CTN-s and affect, followed by ROS. This was continued by questions on the imagined environment, including preference and waste questions. Then, we asked about their plastic-related problem awareness, intentions, and policy measures, before we assessed how well they could put

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themselves into the described forest walk (i.e., transportation). The questionnaire ended with control questions and demographics.

Materials

As in Study 2, we assessed ROS, PA, NA, CTN-s, attractiveness and preference of scenery, likelihood of visiting such a scenery, problem awareness, intentions to use plastic, and policy support (see Table 6 for their Cronbach's α). As an attention check, we asked participants what they imagined (they should enter at least five words). Then, we asked whether and what kind of waste they imagined (open response field with option to click "I have imagined no waste"). To assess how well participants could put themselves into the imagined forest walk, we used an adaptation of the Transportation Scale, which measures how well participants are immersed into the narrative told (Appel et al., 2015). Five of the six original items were adapted to the described forest walk, the other item was used in three versions adapted to our stimuli (e.g., "When hearing the audio, I could lively imagine the rock / apple core / plastic cup").

Audio

We created three 3:32 min audios with a calm voice, relaxing music, and occasional bird sounds. The male speaker invited participants to an imagined forest walk that also included a small river ("[…] Imagine that you are now going for a walk. [pause]. This walk takes you through a beautiful forest. […]"; for details, see S20, in the Supplementary Materials). At three occasions, the audios differed depending on condition (e.g., "[…] you watch the movement of the water until a broken branch [no waste] / a carrot [bio-waste] / a plastic bottle [plastic waste] catches your attention […]"). Similar to Study 2, we asked whether they attentively listened the audio until the end and whether they had any technical problems.

Results

Descriptive results, ANOVA results of group comparisons, and indications for pre-post effects are displayed in Table 6. Explorative correlations among measures can be found in Menzel, von der Heiden et al., 2023, S21.

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Table 6

Cronbach's Alpha, Mean, Standard Deviation, and One-Way Analyses of Variance for All Variables in Study 3

	Full Sample			No Waste		Bio-waste		Plastic Waste				
Variable	**α**	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***F*(2, 235)**	***p***	**η^2**
ROS	.93	4.31	1.42	4.60_{a}	1.54	4.40_{ab}	1.27	3.91_{b}	1.36	5.09	.007	.04
PA pre	.87	2.74	0.67	2.70	0.70	2.83	0.69	2.68	0.62	—	—	—
PA post	.91	2.78	0.81	2.84*	0.87	2.92	0.79	2.57	0.75	—	—	—
PA diff	—	0.04	0.55	0.14_{a}	0.58	0.08_{ab}	0.50	-0.11_{b}	0.53	4.59	.011	.04
NA pre	.86	1.54	0.58	1.45	0.44	1.55	0.65	1.61	0.64	—	—	—
NA post	.90	1.50	0.64	1.23***	0.37	1.39***	0.56	1.90***	0.75	—	—	—
NA diff	—	-0.04	0.49	-0.22_{a}	0.33	-0.16_{a}	0.34	0.29_{b}	0.60	21.78[a]	< .001	.15[b]
CTN-s pre	.90	3.28	0.78	3.21	0.85	3.34	0.84	3.30	0.63	—	—	—
CTN-s post	.91	3.67***	0.76	3.64***	0.84	3.70***	0.76	3.69***	0.65	—	—	—
CTN-s diff	—	0.39	0.58	0.43	0.61	0.36	0.55	0.39	0.58	0.28	.753	.01
Attractiveness of scenery	–	4.14	0.96	4.59_{a}	0.59	4.38_{a}	0.72	3.39_{b}	1.07	37.02[a]	< .001	.23[b]
Preference of scenery	—	4.28	0.95	4.70_{a}	0.51	4.49_{a}	0.71	3.61_{b}	1.17	28.50[a]	< .001	.19[b]
Likelihood of visiting such a scenery	—	4.34	0.88	4.62_{a}	0.51	4.47_{a}	0.85	3.92_{b}	1.06	13.48[a]	< .001	.09[b]
Problem awareness	.75	4.36	0.48	4.35	0.41	4.39	0.45	4.35	0.58	0.18	.834	< .01
Intention	.61	3.28	0.89	3.21	0.85	3.35	0.93	3.29	0.89	0.50	.605	< .01
Policy support	.86	6.28	0.73	6.30	0.58	6.32	0.65	6.21	0.93	0.44	.647	< .01
Transportation	.84	5.30	1.05	5.28	1.25	5.14	0.90	5.50	0.93	2.36	.097	.02

Note. ROS = restoration outcome scale. PA pre = positive affect before audio. PA post = positive affect after audio. PA diff = difference score between PA pre and PA post. NA pre = negative affect before audio. NA post = negative affect after audio. NA diff = difference score between NA pre and NA post. CTN-s pre = connectedness to nature state before audio. CTN-s post = connectedness to nature state after audio. CTN-s diff = difference score between CTN-s pre and CTN-s post. Means with different subscripts differ at the $p = .05$ level by Tukey's HSD post-hoc tests (or Games Howell tests for Welch ANOVAs) in the group comparison. [a]Welch's $F(2, 147.19)$ for NAdiff, Welch's $F(2, 147.11)$ for attractiveness of scenery, Welch's $F(2, 141.81)$ for preference of scenery, or Welch's $F(2, 140.44)$ for likelihood of visiting such a scenery. [b]estimated ω^2.

*$p \leq .05$. ***$p \leq .001$. (Pre-post comparisons).

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Pre-Post Comparisons

PA increased in the no waste condition, $t(80) = -2.22$, $p = .029$, $d = -0.18$, 95% CI [-0.272, -0.015], but not in the other conditions, bio-waste: $t(80) = -1.51$, $p = .135$; plastic waste: $t(75) = 1.77$, $p = .081$) or overall, $t(237) = -1.23$, $p = .222$. Generally, NA was similar before and after the intervention, $t(237) = -1.23$, $p = .222$, but it decreased for no waste, $t(80) = 6.15$, $p < .001$, $d = 0.54$, 95% CI [0.150, 0.294], and for bio-waste, $t(80) = 4.23$, $p < .001$, $d = 0.26$, 95% CI [0.086, 0.238], while it increased for plastic waste, $t(75) = -4.16$, $p < .001$, $d = 0.41$, 95% CI [-0.424, -0.150]. CTN-s increased from pre to post (full sample: $t(237) = -10.39$, $p < .001$, $d = -0.51$, 95% CI [-0.464, -0.316]; no waste: $t(80) = -6.26$, $p < .001$, $d = -0.50$, 95% CI [-0.562, -0.291]; bio-waste: $t(80) = -5.91$, $p < .001$, $d = -0.44$, 95% CI [-0.479, -0.238]; plastic waste: $t(75) = -5.76$, $p < .001$, $d = -0.60$, 95% CI [-0.519, -0.252].

Group Comparisons

Restoration differed between conditions, with higher restoration for no waste compared to plastic, $p = .006$, 95% CI [-1.218, -0.168]. There was a tendency that restoration was higher for bio-waste than plastic waste, $p = .071$, 95% CI [-1.018, 0.032]. PA change differed between conditions, with a higher increase for no waste compared to plastic waste, $p = .011$, 95% CI [-0.452, -0.0475], and a tendency for a decrease in PA for plastic waste compared to the minor increase for bio-waste, $p = .070$, 95% CI [-0.393, 0.012]. Change in NA differed between groups, with a higher increase in the plastic waste condition compared to the no waste, $p < .001$, 95% CI [0.324, 0.694], and the bio-waste condition, $p < .001$, 95% CI [0.261, 0.636]. Change in CTN-s did not differ across conditions. Attractiveness of the scenery was lower for the plastic waste condition compared to no waste, $p < .001$, 95% CI [-1.530, -0.867], and bio-waste, $p < .001$, 95% CI [-1.340, -0.641]. Preference of the scenery was lower for the plastic waste condition compared to no waste, $p < .001$, 95% CI [-1.440, -0.753], and bio-waste, $p < .001$, 95% CI [-1.260, -0.520]. The likelihood of visiting such a scenery was lower for the plastic waste condition compared to no waste, $p < .001$, 95% CI [-1.010, -0.378], and bio-waste, $p < .001$, 95% CI [-0.912, -0.184]. Problem awareness, plastic-related intentions, and policy support did not differ across conditions. Transportation was similar across conditions.

Additional Analyses

Additionally to the main analysis presented here, we run a secondary analyses on an alternative sample, which was also preregistered[4]. For this, additional participants ($n = 12$) were excluded when they imagined plastic in the no waste or the bio-waste condition or reported no waste in the plastic condition. We decided to do so, because for some

4) Deviating from preregistration we did not exclude those participants who reported no waste in the bio-waste condition as the majority of participants did that and some commented that they perceived the mentioned items not as waste in the narrow sense.

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persons it might be natural to imagine waste in the no waste condition (because it is so abundant in everyday encounters) and/or because some people may (unintentionally or intentionally) ignore waste in waste conditions in order to remain in their imagined scenery. Respective analyses for this subsample can be found in Menzel, von der Heiden et al., 2023, S22 and S23. Importantly these alternative analyses revealed the same results, except for transportation (Menzel, von der Heiden et al., 2023, S22).

Discussion

By using guided imagery in an experimental setting, we investigated the effect of plastic waste on restoration. As expected, PA and CTN-s increased, and NA decreased when imagining a walk through a litter-free forest. When plastic waste was mentioned, NA *increased*. Comments by participants emphasized this negative response. In comparison to a litter-free imagination, mentioning plastic evoked lower subjective restoration, a lower increase in PA, an increase (instead of decrease) in NA, lower perceived attractiveness and preference of scenery, and a lower likelihood of visiting such a scenery. For all variables, bio-waste did not differ from no waste. Participants' comments indicated that bio-waste was not perceived as waste in the narrow sense, although "it did not belong there". Noteworthy, the analyses of the subsample revealed that people could transport better into the plastic condition than the bio-waste condition. As there was no difference to the no waste condition, this alone cannot explain our pattern of results. Anyhow, transportation correlated with several of our variables (Menzel, von der Heiden et al., 2023, S21 and S23) and therefore should be considered further in such experiments. As in Study 1 and 2, problem awareness, intentions, and policy support were not affected by waste.

We found that only imaging a forest walk led to beneficial changes in affect and an increase in CTN. Although, we had no non-nature control condition, our findings and previous research (Coughlan et al., 2022; Koivisto & Grassini, 2023; Muneghina et al., 2021) emphasize that guided imagery should be studied further as it is an easy, brief, and universally available method for increasing wellbeing and CTN. Furthermore, as our study showed, it is also useful to study effects of environmental characteristics and therefore might be a cheap alternative to virtual reality systems in both research and for private use.

General Discussion

In three studies, we investigated the effects of (plastic) waste on a restorative walk. In Study 1, we applied a correlational design with high ecological validity, while Studies 2 and 3 were well-controlled experiments. In all studies, we found an increase in current CTN and a decrease in NA after a walk in a (for Studies 2 and 3 litter-free) restorative

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environment; additionally, PA increased in Study 1 and 3. These findings are in line with previous research showing benefits in affect and CTN after nature experiences (Coughlan et al., 2022; Mayer & Frantz, 2004; McMahan & Estes, 2015; Sheffield et al., 2022).

Importantly, these benefits of nature visits were negatively affected by the presence of (plastic) litter. Subjective restoration tended to be lower for littered environments (especially when it was plastic litter; Study 3, and a tendency in Study 2). Furthermore, the increase of PA (Study 3 and a tendency in Study 1), decrease of NA (Studies 2 and 3), as well as attractiveness and preference of the scenery (Studies 2 and 3, and tendencies in Study 1) were negatively influenced by litter; and in the case of affect the effects were even inverted (i.e., decrease of PA and increase of NA in environments littered with plastic). Despite non-significance in some analyses, this result pattern is generally as expected and suggested by previous research (Bielinis et al., 2022; Verlič et al., 2015; Wyles et al., 2016). Noteworthy, effect sizes were much smaller for restoration and affect than for attractiveness and preference ratings, for which they were generally large. The intermediate and mostly non-significant effects from bio-waste in Study 2 and 3 indicate that the effects were plastic-specific and not merely evoked by human-sourced clutter in the scenery.

Besides the main research question, we also asked whether experiences in littered environments influences plastic-related problem awareness, intentions, and/or policy support. In neither of our three studies, we found an effect of waste on one of these variables. In all studies, mean values for problem awareness and especially for policy support were very high (cf. Hartley et al., 2018; Heidbreder et al., 2019), indicating little inter-individual variance. A further limitation is that the used scales were not systematically validated and their Cronbach's α indicated limited reliability. Anyhow, exploratory regressions and bivariate correlations indicate positive associations of restoration and intentions to reduce plastic (all studies) as well as problem awareness and policy support (Study 1; Menzel, von der Heiden et al., 2023, S8, S11). This preliminary finding is in line with other research linking psychological restoration and environmental behaviour (Collado & Corraliza, 2015; Hartig et al., 2007; Rosa & Collado, 2019). However, due to the mentioned limitations, our findings should be interpreted with caution. Further research is needed to investigate the links between restoration and individual plastic consumption and support in respective policy measures.

Limitations

Besides the limitations already mentioned, the conclusions are limited by further aspects. One major limitation of the current work is the high exclusion rate of participants, leading to sample sizes smaller than suggested by the a-priori power analyses. This might in part explain why some comparisons are only marginally significant (e.g., ROS in Study 2). Although this high exclusion rate is very unfortunate, it hints us at considering

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higher drop-out assumptions in future a-priori sample size analyses and to reconsider bio-waste as a control condition. Comments by participants indicated that when presented visually (Study 2) bio-waste was difficult to recognize as such and when presented verbally (Study 3) it was sometimes not considered as 'waste' in the narrow sense. Future studies should therefore take care that the active control condition is perceived as it was intended.

In fact, knowing what nature means for participants and whether pollution is perceived an inherent characteristic of nature visits is relevant for the interpretation of our results; it might have even biased them. In 2019, a representative sample of Germans was asked to report associations with nature (open response field to the question 'What is nature for you? Mention as many words as come to your mind.'; Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit & Bundesamt für Naturschutz, 2020): Only a minority stated 'pollution', while many mentioned 'restoration' among others. Although, this might indicate that pollution may not be considered a big problem in German nature, it contradicts our finding of Study 1 in which 79% of participants saw litter during their restorative walk. Rather, the findings of the mentioned study might reflect that many associations were related to an ideal nature. Considering this, not fulfilling the expectations of such an ideal nature in a guided imagery might partly explain that we found the largest effect sizes in Study 3.

Our results are further limited by the sample characteristics, namely German convenience samples. This has several consequences. For example, in convenience samples, the likelihood of biased samples is relatively high. In fact, our study invitations mentioned restorative walks and, therefore, might particularly attract stressed people and/or those using (nature) walks as a coping strategy. Furthermore, our sample is culturally biased as it was recruited only in Germany. Although having data from only one high-income country in the global north is very limited, it is nevertheless a relevant country to consider. Germany is among the high-consumption countries (PlasticsEurope, 2020) and a relatively high amount of German plastic waste is found even in the Arctic (Meyer et al., 2023). Therefore, German viewpoints are relevant for investigating links of litter and restoration, and especially important for studying predictors for reduced consumption and plastic-related policy support.

Conclusions

Our work consisted of three studies, of which two were experimental, allowing us to replicate our general pattern of results using three different methodological approaches, namely actual walk, video of a forest walk, and a guided imagery. The results show that plastic waste in a restoring natural environment can negatively impact subjective restoration, affect, and the perception of the scenery. Overall, our results indicate harmful effects on human wellbeing, but no effects on relevant factors that are important to

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tackle the plastic pollution. However, the fact that litter did not affect the increase of current CTN after nature experiences gives hope that the important link between CTN and pro-environmental behaviour (Mackay & Schmitt, 2019; Whitburn et al., 2020) is not compromised. More research is needed to better understand predictors for reduced plastic consumption. As support in policy measures is already high and plastic pollution must be addressed by different instances (e.g., individual, policy, producers, retailers), multifaceted approaches are needed to tackle the global crisis of plastic pollution.

Openness and Transparency Statements

The present article has been checked by its handling editor(s) for compliance with the journal's open science and transparency policies. The completed *Transparency Checklist* is publicly available at:
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Author Contributions.

Claudia Menzel: Conceptualization. Methodology. Investigation. Formal analysis. Writing – original draft. Writing – review & editing. Visualization. Supervision. Project administration.

Leonie von der Heiden: Conceptualization. Methodology. Software. Investigation. Visualization. Writing – review & editing.

Imke Tretau: Conceptualization. Methodology. Software. Investigation. Writing – review & editing.

Pia Wissel: Conceptualization. Methodology. Software. Investigation. Writing – review & editing.

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Diversity Statement. In the list below, the check mark (☑) indicates which steps were taken to increase diversity within the context of this paper. Steps that were not taken or did not apply are unmarked (☐).

- ☐ Ethnically or otherwise diverse sample(s)
- ☐ Gender balanced sample(s)
- ☑ Inclusive gender measure
- ☐ Inclusive materials
- ☑ Sampling justification
- ☑ Extensive sample description

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- ☑ Discussion of generalizability
- ☑ Diverse reference list
- ☐ Underprivileged / minority author(s)
- ☑ Early career author(s)
- ☐ Degree of privilege/marginalization considered in authorship order
- ☐ Author(s) from sampled population (avoiding 'helicopter science')

Data Availability. All materials, data, and scripts can be found in Menzel, Wissel et al., 2023.

Supplementary Materials. The following table provides an overview of the accessibility of supplementary materials (if any) for this paper.

Type of supplementary materials	Availability/Access
Data	
Studies 1–3 questionnaire results.	Menzel, Wissel et al., 2023
Code	
R Code (and data) for group and pre-post situation comparisons.	Menzel, Wissel et al., 2023
Material	
a) Video simulating forest walk.	Menzel, Wissel et al., 2023
b) Audio simulating forest walk.	Menzel, Wissel et al., 2023
Study/Analysis preregistration	
a) Pre-registration of pilot study.	Menzel et al., 2021
b) Pre-registration of first study.	Menzel & Wissel, 2022
c) Pre-registration of second study.	Menzel & von der Heiden, 2022
d) Pre-registration of third study.	Menzel & Tretau, 2022
Other	
Detailed procedures, additional tables.	Menzel, von der Heiden et al., 2023

Badges for Good Research Practices.

Open data: YES.

Open code: YES.

Open materials: YES.

Preregistration: YES.

Diversity statement: YES.

Note: YES = the present article meets the criteria for awarding the badge. NO = the present article does not meet the criteria for awarding the badge *or* the criteria are not applicable.

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