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# The Restorative Health Benefits of a Tactical Urban Intervention: An Urban Waterfront Study

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Increasing access to urban waterfronts holds much promise for promoting healthy behaviors. While many US cities are revitalizing their waterfronts, the health and well-being benefits associated with these urban design initiatives are largely unknown. Tactical urban interventions (such as parklets and pop-ups) are short-term projects that experiment with and gather input on potential urban design changes. To date, the effect of these projects on individual health outcomes has not been measured. This reports a pilot quasi-experimental study which compares real-time exposure to an urban waterfront that was manipulated to provide a control vs. an intervention "treatment" condition that increased levels of comfort and fascination in the setting. Our study utilized a repeated-measures crossover randomized design and captured measures of stress and well-being whilst participants walked in each condition ($n = 23$). First, real-time stress was captured using a smart watch to capture heart rate variability (HRV) during the walk, including for a resting baseline period of measurement pre-walk. Second, subjective mood (i.e., stress, arousal, and hedonic tone) was assessed pre and post-walk using the UWIST MACL Mood Scale (Matthews et al., 1990). Third, two measures of perceived restorativeness (i.e., fascination and being away) were captured pre and post-walk using the PRS Scale (Hartig et al., 1997), together with two indicators of social well-being (i.e., place belonging and social trust). Results showed a statistically significant reduction in perceived stress from walking in the intervention, as compared to the control condition ($p < 0.05$). This was matched by positive and statistically significant change on our measures of perceived restoration and social well-being from walking in the intervention. Results showed an increase in parasympathetic response (as measured by HRV) from exposure to the intervention, indicating lower stress, and the opposite pattern whilst walking in the control condition (i.e., increased stress), albeit only significant at the 0.055 level. We discuss future directions for this type of experimental study design and how findings on short-term tactical urban designs could be usefully applied to direct longer-term urban design changes for public health gains. We also consider how smart watches/phones can help capture valuable data in real world, real-time contexts to help understand people-environment interactions.

**Keywords: blue health, stress, psychological well-being, heart rate variability, perceived restorativeness, social well-being, urban waterfront, urban design**

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## INTRODUCTION

This paper focuses on the restorative health outcomes of walking in an urban waterfront location. It builds on a small but growing body of research (mostly from Europe) showing the health benefits of exposure to our coasts, rivers and canals—defined as "blue health" in the literature (Gascon et al., 2017). We define "blue" as any environment which fosters interactions with water—in the context of this study, walking along an urban waterfront in West Palm Beach, Florida. Our study focuses on psychological restoration and the ability of a waterfront setting to promote recovery of psychological and physiological resources in the general population.

Understanding how blue environments promote health benefits requires an understanding of wider theoretical perspectives that describe how contact with nature supports our well-being. It's believed that there are four main pathways by which nature contact (including blue environments) may support health (Hartig et al., 2014), which we subsequently refer to as the nature-health model. Two of the pathways are direct (i.e., the nature environment has a direct impact on our health without us consciously being aware of it); in the case of blue environments, one direct pathway is air temperature regulation, for example, water bodies help cool air and mitigate urban heat island effects. A second direct pathway is stress regulation and the impact of nature environments on our physiological reactions to stress (Ulrich et al., 1991). Our stress response is regulated by the Autonomic Nervous System (ANS), a part of our nervous system over which we have little voluntary control. The ANS plays an important role in modulating responses to stress (Park et al., 2010). The ANS has two interrelated biologic systems; the sympathetic system (that activates our fight or flight response) and the parasympathetic system (that slows down the stress response and induces calm). These two systems work together to produces *allostasis*, our bodies ability to maintain stability through change. There is evidence to suggest that parasympathetic activity is higher from contact with nature and accounts for the stress regulatory benefits of green—and potentially blue—environments (Egorov et al., 2017). The other two pathways in the nature-health model are physical activity and social contact i.e., we tend to be more active in natural environments, and we are more likely to meet people there, either on an impromptu basis or for organized activities. In these latter two scenarios, there has to be direct interaction with the natural environment i.e., we consciously choose to engage and/or enter that setting (Hartig et al., 2014).

In addition to the stress regulation theory (SRT) outlined above, another complementary but distinctive theory posits that our response to the blue environment is primarily a cognitive one, and that the soft stimuli of water—the patterns and light falling on it as it flows—promote our involuntary attention and recovery from cognitive fatigue. Called Attention Restoration Theory (ART) (Kaplan and Kaplan, 1989), it argues that "fascination" in the natural environment–in this context, the curiosity and wonder that water sparks–is a critical environmental cue in the process of psychological restoration. In addition to fascination, natural settings are believed to promote restoration, owing to their ability to promote a sense of *being away* (psychological and/or geographical distance from routines that impose demands on directed attention), *extent* (a setting "rich enough and coherent enough so that it constitutes a whole other world" with sufficient scope to engage the mind (Kaplan, 1995, p. 173) and compatibility (a good fit between an individual's purposes or inclinations and the kinds of activities, supported, encouraged or demanded by the setting). Whilst settings other than nature can promote restoration, ART proposes that natural settings have a greater proportion of these four qualities than urban environments.

There is some evidence to suggest that water is a powerful restorative environment. The evidence has recently been brought together in a systematic review (Gascon et al., 2017) which found limited evidence showing the benefits of blue environments—mostly coastal settings–to physical health and mental well-being. In their review, Gascon et al. (2017) identified only 3 studies that explored mood outcomes (including increased happiness) from contact with blue space, across a range of ages and settings. Using a smart phone app, British adults reported being happier in marine and coastal areas, as well as freshwater, wetlands and flood plains, as compared to being in any other type of urban or rural setting (MacKerron and Mourato, 2013). In Canadian children (aged 11–16), increasing exposure to water bodies (ocean, lakes, rivers, streams) was associated with better emotional well-being (Huynh et al., 2013). In Spanish children (aged 7–10 years) time spent on the beach (7–10 years) was associated with reduced emotional problems and greater pro-social behavior, as reported by their parents (Amoly et al., 2014). One further study showed that increased exposure to coastal areas is associated with better mental well-being (as measured by GHQ which captures minor psychiatric problems) (Alcock et al., 2015). Whilst the findings are encouraging, there is a paucity of evidence in relation to mental well-being outcomes, with need for improved experimental design and better outcome measures. Important predictors of psychological well-being—including the perceived restorativeness of the setting—have not been captured in many studies, and there is a paucity of evidence exploring social health outcomes, which are posited to be an indirect health benefit from contact with nature settings (Hartig et al., 2014).

There are limited studies showing how nature settings impact physiological stress in real-time in real-world outdoor settings (as opposed to the laboratory where the bulk of this research has been carried out) and inevitably, this works grows in small sample sizes. This evidence has been systematically reviewed by Kondo et al. (2018), indicating that health sensors capturing heart rate, blood pressure in parallel with self-report measures currently offer the most convincing evidence that spending time outdoors, particularly in settings with green space, may assist with stress regulation. Of 42 studies that met the review criteria, HRV was found to be one of the most consistent and reliable measures (17 studies identified).

Heart rate variability (HRV) is the variation in the time intervals between heartbeats and has typically been used as an indicator of autonomic nervous system (ANS) control/functioning. A higher HRV suggests an increased adaptability of the ANS and is associated with better health

(Brown et al., 2013). HRV is measured using a range of outcomes including low frequency/high frequency (LF/HF) ratio, interbeat interval (IBI), R-R interval (Gidlow et al., 2016; Gladwell et al., 2016), room mean squared of successive differences (rMSSD), standard deviation of normal-to-normal-intervals (SDNN). Thirteen studies have captured HRV continuously during exposure to nature settings using (mostly) portable ECG monitors (see Kondo et al., 2018). Whilst previous research has shown that exposure to nature increases HRV (Park et al., 2007, 2010; Gladwell et al., 2016) to date, no study, as far as we know, has shown real-time stress outcomes, as measured by HRV, from exposure to a blue environment.

Building on the above evidence, we hypothesized that exposure to a stretch of urban waterfront promenade (by walking) would have a beneficial effect to psychological and physiological restoration, but that the rate of restoration would be greater in an intervention condition—designed to improve engagement and comfort levels—as compared to the same site with no design intervention (the control in our experiment). Hereon, intervention condition refers to stretch of waterfront receiving a design intervention vs. a control condition, referring to the same stretch of urban waterfront with no design intervention in place.

*Hypothesis 1*: Psychological restoration—as measured by the University of Wales Institute of Science and Technology Mood Adjective Checklist (UWIST MACL), the Perceived Restorativeness Scale (PRS) and social well-being attributes—will increase at a greater rate from walking in the intervention condition as compared to the control condition.

*Hypothesis 2:* physiological restoration—as measured by HRV (and an increase in entropy/ increase in parasympathetic response)—will increase to a greater degree in the intervention condition as compared to the control condition.

# METHODS

## Study Design

### Recruitment

All participants were self-selected to the walk. A total of 23 participants took part, aged between 25 and 45. Recruitment was carried out by Street Plans Collaborative using their participant recruitment pool and snowball sampling methods. Information was distributed to interested recruits via e-mail with sign up via an associated web. We aimed to recruit a racially diverse sample representative of the West Palm Beach population and equal numbers of men and women. Signed consent was a condition of taking part and required prior to the start of the experiment. Ethical approval for the study was provided by University of Virginia's Social and Behavioral Sciences Institutional Review Board (SBS IRB).

## The Environmental Exposure Settings

The West Palm Beach, FL. waterfront promenade was selected for the study, as part of a wider revisioning urban design project for the downtown district of the city. The site for the experiment was located on the waterfront promenade, directly east of the intersection of Flagler Drive and Datura Street. This site was chosen based on the following criteria: it offered sufficient space and scope for a design intervention that would not impede pedestrian, bicycle, or visitor Segway tours; it offered a distillation of the waterfront's main challenges that included lack of shade, comfortable places to sit, and any compelling reasons to linger and engage with the setting; it was in close proximity to the visitor center where pre and post-survey data could be gathered, alongside the participant consent process. This was a single site study designed as described below to provide a control vs. intervention condition (illustrated in **Figure 1** below).

The intervention condition was a low-cost, temporary change to the waterfront intended to improve the quality, comfort and enjoyment of the place, and drawing on methods from tactical urbanism. In this case, the intervention was designed to boost psychological restoration by increasing two attributes associated with this process i.e., fascination and being away. The design intervention for the West Palm Beach waterfront promenade included a series of "fascination frames" that connected participants with the aesthetic and cultural history of the water, and took them away from the everyday context (promoting a sense of being away), together with moveable chairs and tables, planters, and shade and screen planting (bamboo) to the adjacent roadway to increase comfort levels and reduce noise pollution (see **Figure 1** below which also shows the control condition). The installation of the intervention was carried out by Street Plans Collaborative, a leading US urban planning and design practice helping enhance long-term place making efforts using short-term tactical interventions to establish best practice and outcomes.

## Experimental Design

We employed a crossover repeated measurements design (i.e., the participants cross over from one exposure condition to another), randomly assigning our participants to one of two groups. Each subject experienced both the intervention and control condition. To eliminate order effects (i.e., the varying psychological effect created by the order in which people experience a change of setting) we conducted two "pairs" of walks over 3 consecutive days in Spring 2017. Group A were exposed to the control condition on Day 1, and to the intervention condition on Day 2 at exactly the same time of day (afternoon). The intervention was put in place early in the morning on Day 2. Group B were exposed to the intervention on Day 2 (morning) and to the control on Day 3 (morning). The intervention was removed post-testing on Day 2. See **Figure 2** below.

Climatic conditions were similar over the 3 days of the experiment; the site experienced no rain and the temperature was relatively consistent at 73 degrees Fahrenheit with sunny conditions during the period of the experimental exposure.

## Outcome Measures

### Psychological Measures

#### *Subjective mood*

Mood was measured using a shortened version of the University of Wales Institute of Science and Technology (UWIST) Mood Adjective Checklist (MACL) (Matthews et al., 1990; Schultheiss

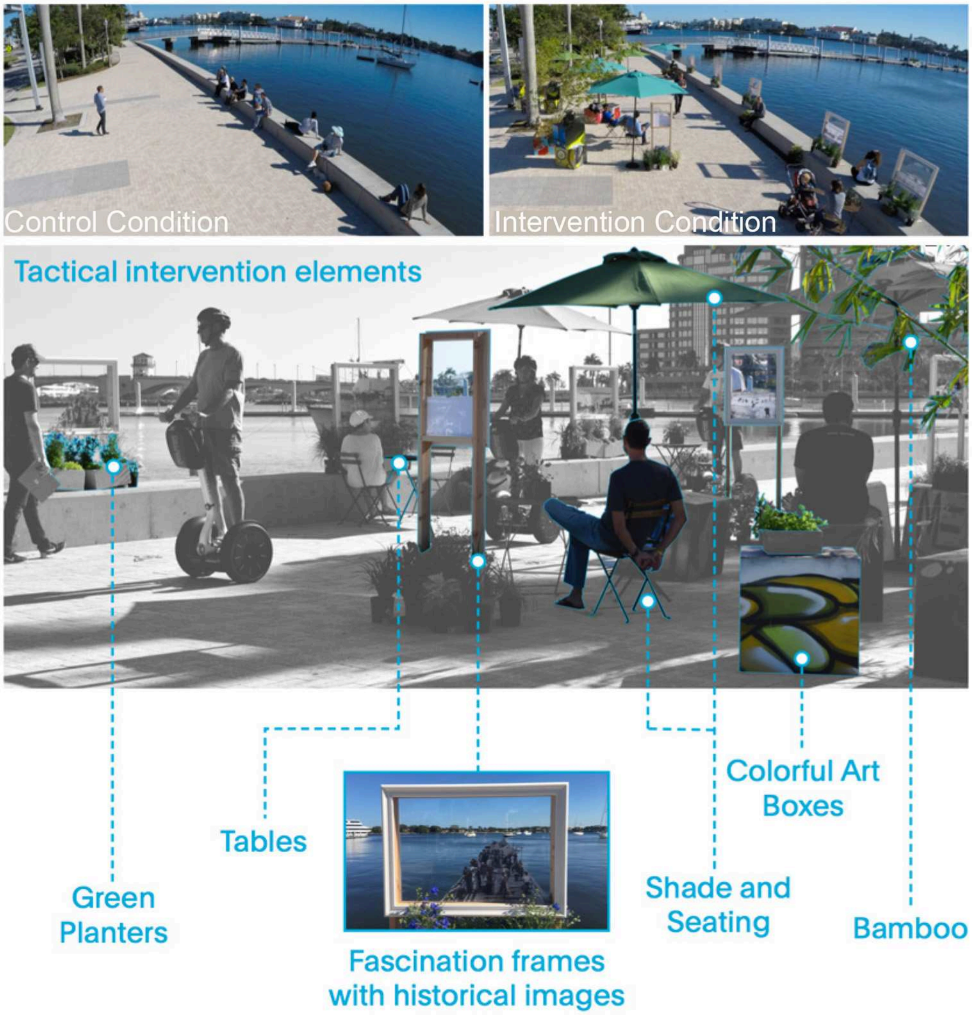


**FIGURE 1 |** The control and intervention conditions © Happy City.

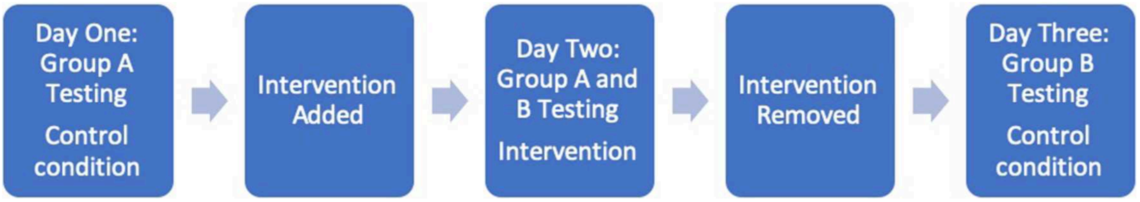


**FIGURE 2 |** Experimental design and exposure protocol.

and Brunstein, 1999) to measure participants' hedonic tone, energy and stress (tense arousal). Hedonic tone measures a person's affective state (i.e., degree of happiness and sadness). The UWIST MACL has a total of 12 question, 4 questions for each of the three moods; subjects respond to a 4-point Likert scale for each question (ranging from "definitely," "slightly," "not much," "definitely not").

#### *Perceived restorativeness scale*

Two items from the Perceived Restorativeness Scale (Hartig et al., 1997) measuring the core components of psychological restoration, "being away" and "fascination" i.e., the level of interest in the setting, ranked on a 5-point Likert scale, (5) indicating a high restorative value to (1) a low restorative value. These two items have been identified (Gonzalez et al.,

2010) as being most robust for intervention analysis of this kind.

***Social well-being***

Social well-being is measured using two items validated in restorative environment research, one measuring social trust ("if you lost a wallet with $100 in it, how likely are you to have it returned"), the other measuring perceived place belonging ("how strongly do you feel you belong to this place"), both ranked on a 5-point Likert scale, with a higher value indicating a greater perception of social trust and place belonging.

### Physiological Measures

***Heart rate variability (HRV)***

Physiological data was collected using the Microsoft Band 2 (Microsoft, 2016). The Sensus app (Xiong et al., 2016) collects the heart rate, galvanic skin response (GSR), skin temperature, and activity data from the band in real-time. This device has been used in previous research measuring physiological responses (e.g., Lopez-Samaniego and Garcia-Zapirain, 2016). From the Microsoft Band we computed a permutation entropy based on heart rate variability using the R-R intervals from the band (see section Data analyses below).

## Data Analyses

Data analyses for the pre and post-psychological well-being data was carried out using SPSS (version 22) using Analysis of Variance (ANOVA) factoring walk (pre and post) and setting (control vs. intervention). Analyses was carried out on the change data i.e., the pre minus post-scores for the control and intervention conditions. Differences between environmental exposure outcomes for four further subjective variables (Being Away (PRS), Fascination (PRS), Belonging and Social Trust) was tested using the paired Wilcoxon Test, a test of difference for paired/matched samples.

Data analyses for the physiological data was carried out using MATLAB (version 2017B). We examined the R-R interval data using permutation entropy (methods of observable heart rate dynamics, where $m = 3$, $m = 4$ and order of the permutation were defined in the permutation measurement) which requires a minimum of ∼100 samples for an accurate calculation. Although the device did at times produce values which were extreme, the direction (an increase or decrease of R-R measurements) can mostly likely be considered to be correct. Permutation entropy examines the complexity of the time series using the rank order of the sequence. Thus, this measurement captures directional changes in the heart rate dynamics, rather than the overall magnitude. This is a more ideal entropy measurement since the data is very noisy/corrupted. Other methods which measure magnitude of time such as sample entropy and even standard deviation were deemed to be not as appropriate since they will be more sensitive to the corruptive signal and have a higher potential to propagate false findings (Napoli et al., 2018).

### HRV Time Segments

The windowing of the time series was constrained by the trade-off of requiring a minimum of 100 samples (∼2 min of data) and the minimal time it took the cohort of subjects to complete their route/walk (∼4–5 min). Thus, as we increased the window size and overall segmented windows, subjects that completed the route in shorter time did not generate enough data. Extending the window size would cause us to drop additional subjects out of the study and reduce the statically power of the non-parametric means test. Therefore, the entropy calculation was processed with two different windowing schemes to better depict the physiological implications of the imposed experiment as function time. The first windowing method simply utilizes the complete 200 time instances as a single window. This allows us to apply a more stringent permutation entropy parameter of $m = 4$ which increases the total amount of possible permutations for the similarity criteria. This more stringent parameter can be applied since the length of the sequence is larger. The second windowing method is where two windowed time segments were applied to the walking and rest phases of the study. This created two 100 time instances in each window which we relaxed the constraint to the minimal permutation length of $m = 3$. This allowed us to maintain 21 subjects in the study, with only 2 subjects removed owing to insufficient data.

### HRV Subject Standardization

The subjects were given a rest and walk phase during the control day and intervention day of the study. Since each subject's autonomic activity may differ day to day, a standardization was imposed on the data to better normalize changes across the different days. This was achieved by combining the resting and intervention entropy measurement together for each subject and then z-scoring the data. This allowed the resting phase to be utilized as a baseline/reference during the standardization. Once standardized, we removed the resting data (our reference as to how that individual changed relative to baseline rest) to strictly evaluate the implications of the walking and intervention phase of the study. We ran a Wilcoxon rank sum test to examine the significance.

# RESULTS

## Descriptive Statistics

### Demographics

The majority of our participants were aged between 25 and 34 (44%); 48% were male and 52% were female; participants were predominantly White Caucasian (61%) with high socioeconomic status (i.e., in paid work, living comfortably on current income, and having attended higher education). See **Table 1** below.

## Subjective Well-Being Measures

We did not find evidence of order effects (i.e., exposure to Control>Intervention vs. Intervention > Control) on either the subjective mood scale (UWIST MACL), perceived restorativeness (PRS) or social well-being variables. However, we did find statistically different baseline scores for subjective well-being between the Intervention and Control conditions; therefore, the statistical tests for subjective well-being are carried out on the "change data" i.e., the rate of change on a scale over time

**TABLE 1** | Characteristics of the study population, $n = 23$.

| | Total mean (SD) | Percentage sample |
|---|---|---|
| **Gender** | | |
| Male | | 47.8% |
| Female | | 52.2% |
| **Age** | | |
| 16–34 | | 43.5% |
| 35–44 | | 30.4% |
| 45–54 | | 17.4% |
| 55+ | | 8.6% |
| **Work status** | | |
| In paid work | | 87% |
| Not in work owing to retirement, caring for family, unemployed | | 13% |
| **Ethnicity** | | |
| White | | 61% |
| Hispanic, white | | 22% |
| Hispanic, black | | 9% |
| Black | | 9% |
| **Subjective income coping** | | |
| Living comfortably/ coping | | 84% |
| Finding it difficult/very difficult | | 16% |
| **Length of time living in n/hood** | 6.8 years (6.12) | |
| **Frequency of visits to exposure setting** | | |
| Several times/week | | 47.8% |
| Several times/month | | 34.8% |
| Several times/year | | 8.7% |
| Not in past year | | 8.7% |

(calculated as pre-walk score minus post-walk score) using data methods set out in Roe and Aspinall (2011).

### UWIST MACL

Results show positive change from exposure to the Intervention condition on Arousal, Hedonic Tone and Stress (**Table 2** below). The ANOVA analysis shows this change was statistically significant for stress only. The intervention condition reduced perceived stress as compared to the control condition which increased stress (illustrated in **Figure 3** below). The effect size is a measure of the magnitude, or size, of an effect (partial eta squared); it shows the scale of difference between the effect of the two settings on emotional wellness. According to Cohn's rules of thumb for interpreting effect sizes (Cohen, 1988) the effect size on the stress variable is large ($\leq$0.138) (**Table 2**) but we err caution reading this result owing to the small sample.

In summary, we also found a statistically significant positive effect of walking in the intervention condition on perceived stress, plus a direction of change in arousal and hedonic tone that is aligned with Hypothesis 1 and where—with increased power—we may see significant change.

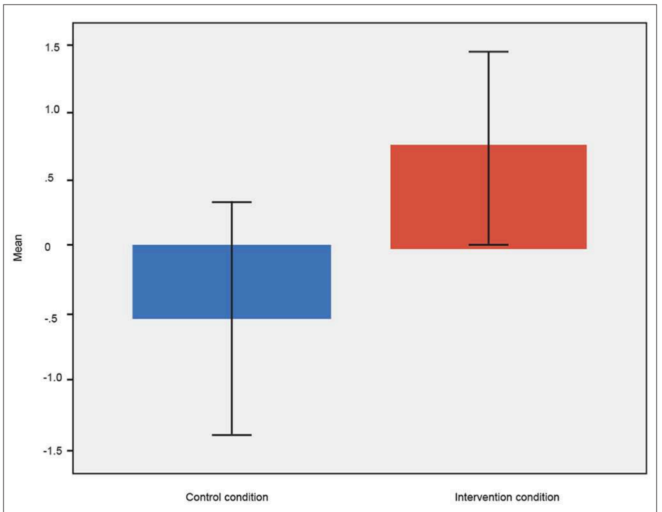


**FIGURE 3** | Differences in pre–post-change on the stress scale between intervention and control condition. Note: a bar above zero denotes positive change in stress, a bar below zero denotes negative change in stress. The vertical lines in the figure indicate 2 standard errors about the mean (95% confidence intervals) and give an approximate measure of significance for those lines which do not cross the horizontal zero line.

### Perceived Restorativeness (PRS)

Perceptions of the restorative attributes of "being away" and "fascination" increased in the intervention walk as compared to the control, and the difference was statistically significant. See **Table 3** below.

### Social Well-Being

Social well-being was measured by two variables capturing place belonging and perceived trust in place (i.e., likelihood of having your wallet returned if lost). Subjective social well-being increased from exposure to the intervention condition, as compared to control, and the difference was statistically significant.

## Physiological Indicators (HR and HRV) ($n = 21$)

**Figure 4** below shows the change in the difference in the timing of the R-R Intervals using permutation entropy for the Control vs. Intervention. In order to standardize the data for analyses and compare subjects across the same time window, two subjects were removed since they completed their walk at a faster pace. Walking in the Intervention condition was associated with an increase in entropy (indicative of an increase in the parasympathetic response and lower stress); walking in the Control condition was associated with a decrease in entropy, indicating a decrease in parasympathetic response (higher stress). This difference between the control and intervention was not statistically significant ($p > 0.05$), but the trend is in the right direction of our hypothesis and of marginal significance. The trend demonstrates that the Intervention may be associated with an increase in heart rate dynamics (increase in entropy/ increase in parasympathetic response) as compared to the Control.

**TABLE 2 |** Change in subjective well-being to environmental exposure setting, $n = 23$.

| Mood variable | Control | | Intervention | | Repeated measures ANOVA result for changes in mood between setting |
|---|---|---|---|---|---|
| | Pre-walk (mean/SD) | Change pre-post (mean/SD) | Pre-walk (Mean/SD) | Change pre- post (mean/SD) | *F, df*, partial eta squared, *p*- value |
| Arousal | 11.52 (2.11) | 0.13 (1.84) | 12.22 (2.81) | −0.83 (2.04) | 2.77, 22, 0.11, 0.10 |
| Hedonic tone | 14.13 (1.79) | 0.00 (1.76) | 14.52 (1.28) | −0.78 (1.17) | 2.87, 22, 0.12, 0.10 |
| Stress | 6.22 (2.39) | −0.52 (2.06) | 6.52 (2.33) | 0.74 (1.71) | 5.90, 22, 0.21, 0.02* |

*Change data denotes a change from pre-walk to the post-walk mean; a negative value for arousal and hedonic tone indicates positive change pre-post-walk; a positive value for stress denotes a positive change pre-post-walk. *Statistically significant result at p < 0.05.*

**TABLE 3 |** Changes in Perceived Restorativeness (PRS) and social well-being to environmental exposure setting, $n = 23$.

| Variables | Control Mean (SD) | Intervention: Mean (SD) | Significant difference between exposure settings (paired Wilcoxon Test) |
|---|---|---|---|
| Perceived Restorativeness: Fascination | 3.57 (1.04) | 4.43 (0.59) | $p < 0.001$ |
| Perceived Restorativeness: Being Away | 3.91 (0.95) | 4.61 (0.58) | $p < 0.01$ |
| Place Belonging | 3.83 (1.23) | 4.74 (0.67) | $p < 0.05$ |
| Social Trust | 2.17 (0.83) | 3.00 (1.09) | $p < 0.01$ |

*A higher mean score indicates a positive change.*

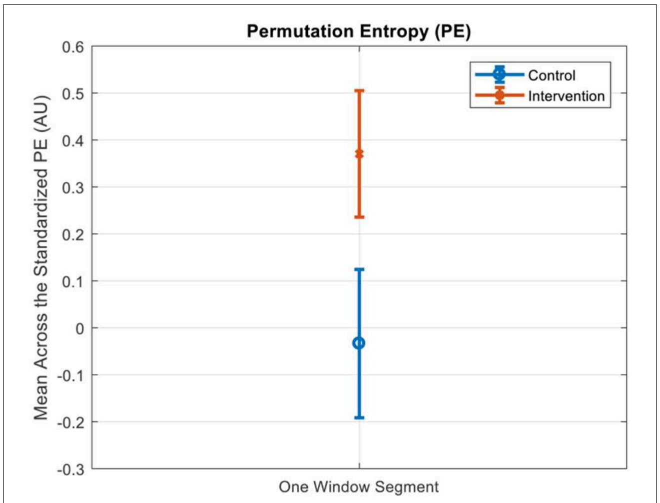


**FIGURE 4 |** This figure provides the means and standard errors of the Permutation Entropy calculation ($m = 4$, accounting for equal permutations) which was standardized using the individual's resting data (Intervention vs. Control, $n = 21$, using 200 time instance samples for the PE calculation).

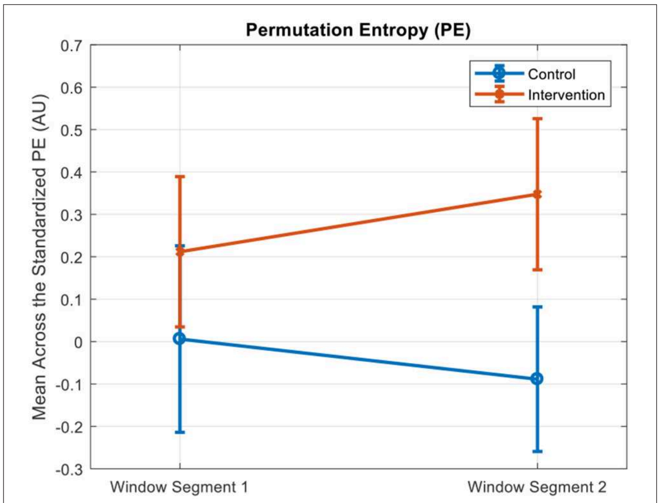


**FIGURE 5 |** This figure provides the means and standard errors of the Permutation Entropy calculation ($m = 3$, accounting for equal permutations) which was standardized using the individual's resting data (Intervention vs. Control, $n = 21$, using 100 time instance samples for the PE calculation).

Result pertaining to **Figure 4** using 200 time Samples to calculate permutation entropy: [$T$-Test $P$-Values at $p = 0.055$ (Rank Sum $P$-Values ($p = 0.0527$)].

Result pertaining to **Figure 5** using 100 Samples to Calculate Permutation Entropy: [$T$-Test $P$-Values ($p = 0.4531, p = 0.0583$) (Rank Sum $P$-Values ($p = 0.6507, p = 0.0871$)].

## DISCUSSION

We had two hypotheses in relation to psychological and physiological changes from exposure to an urban waterfront with a tactical design intervention vs. without. Firstly, with regards to Hypothesis 1, we anticipated psychological restoration—as measured by UWIST MACL, the perceived restorativeness scale (PRS) and social well-being (i.e., belonging and trust)—would increase at a greater rate from exposure to the intervention condition as compared to the control condition Our results support this hypothesis, with positive and statistically significant change on perceived stress, perceived restorativeness and perceived social well-being from exposure to the intervention condition as compared to the control condition. Findings in arousal and hedonic tone were not statistically significant but in the anticipated direction (i.e., positive increases from exposure to the intervention setting). We did not anticipate that exposure to the control condition would increase levels of perceived stress (as illustrated in **Figure 3**).

With regards to Hypothesis 2, we anticipated that physiological restoration—as measured by HRV (and an increase in entropy/increase in parasympathetic response)—will increase to a greater degree in the intervention condition as compared to the control condition. We are not able to reject our null hypothesis that the control and intervention demonstrate similar heart rate dynamics. However, these results still provide an interesting story demonstrated in **Figures 4**, **5** examining the heart rate dynamics over a function of time. In **Figure 4**, we can see that during the intervention phase of the study the heart dynamics begin to highlight a stronger parasympathetic response over time when compared to the control condition. This insinuates the possibility that specific urban designs may influence these heart rate dynamics over time and have possible health benefits. We did not anticipate that walking in the control condition would be associated with a decrease in entropy, indicating a decrease in parasympathetic response (higher stress).

Results, therefore, for exposure to the control condition are surprising, and at odds with the literature showing access to water has a positive effect on psychological well-being (Gascon et al., 2017). The control environment was not an unpleasant place; it was a safe, landscaped promenade featuring views of water, boats and palm trees. We anticipated it would promote well-being. But we believe that noise pollution from the nearby road, together with lack of shade and comfort were factors in aggravating participants stress and arousal responses in this setting. Informal interviews carried out with participants post-exposure supports this view, with participants reporting that the intervention condition offered more opportunity for comfort, shade and seating. Qualitative data gathered post-walk also indicated that the intervention piqued fascination in the local history of the site.

Whilst carried out in a small sample, our study has implications for urban planning and public health. Of interest for urban designers is how the PRS variable of fascination was manipulated alongside an urban waterfront. This suggests that overly blank, underperforming spaces elsewhere in a city may be improved by offering more attributes that deliberately promote fascination and curiosity and improve comfort levels. Additions of flora, seating and shade, screening noise and inserting public art for instance, would all appear to offer opportunities for increasing comfort, engagement and well-being. Of interest to public health practitioners is the potential for urban waterfronts (and other urban water settings) to improve psychosocial well-being and stress regulation. The integration of water in public spaces has the potential to improve public health, health equities, and reduce social-economic inequalities by improving access and the quality of urban waterfronts.

In summary, our results are important in three respects. First, exposure to urban waterfronts are not uniformly restorative or necessarily good for well-being, as measured over the short-term. Factors such as comfort, shade and noise likely play a role. Second, a low-cost tactical design intervention that deliberately improves comfort, shade and promotes the restorative attributes of "fascination" and "being away" can have a significant effect on psychological well-being. Third, tactical urban interventions have a positive role to play in showing—over the short-term—how public spaces can be modified to improve health and well-being, and offer an important evidence-based approach prior to large investment infrastructure change. Finally, as shown by our study, urban design strategies need not necessarily be costly or intricate; simple design interventions can boost well-being.

## LIMITATIONS

Our sample size had limitations resulting in low statistical power and we found non-significant (*ns*) results on three (out of eight) outcome measures. The practicality of carrying out studies using mobile health sensors in the real-world requires small sampling procedure (at least for pilot studies of this nature) and requires replication. In addition, there is likely to be a degree of self-selection bias in our study. Participants were self-selected from a recruitment pool, and the decision to participate in the study may reflect bias—and some familiarity—with the tactical urbanism methods of Street Plans Collaborative.

The study design imposed numerous limitations in which the cadence of each individual ultimately dictated the total amount of the data collected per individual—i.e., some individuals spent more time at the intervention than others. Based on our analysis approach, this caused us to drop subjects out of the study, not due to data quality but rather the inability to do an equivalent comparison across time intervals. This time/data limitation ultimately drove additional problems such as larger windowing paradigms, standardization of the data, and statistical power for the hypothesis tests. For example, if we additionally increase the length of time in the segments, we begin to drop subjects out of the analysis since the length of time is inconsistent amongst subjects, thus causing a lack of data for those with shorter time segments. Since we drop subjects out of analysis we then lose statistical power for the analysis. Thus, we are stuck with a difficult trade-off. If we choose to change the windowing parameters, there is not a consistent trend because of these trade-offs, which makes the sensitivity of the results vary as a function of these trade-offs. For future studies, the cadence of participants should be controlled to standardize study length. This will ensure minimally dropped participants and enable a better sensitivity analysis to evaluate trade-offs of windowing and heart rate complexity metrics.

In addition, there are a number of challenges in undertaking these kinds of real-world experiments. First, recruitment needs to allow for attrition during a crossover experiment carried out over 3 (or more) days. We recruited 30 participants but lost 7 participants over the course of the experiment. Secondly, whilst we were fortunate to have consistent weather conditions over 3 days (and deliberately conducted our experiment outside of identified severe weather periods in Florida) the risk of rain/wind is a threat to any quasi-experiment. Participant turn-out rates can be seriously affected when experiments are rescheduled. Researchers need to make provision for such eventualities, to build flexibility into their program planning to allow field work to be extended and budget for increased recruitment efforts. All of these complexities can result in a reduction in the number of observations and this is a reality—and limitation—of this type of real-time data capture in the field. Measuring real-time physiological response of urban interventions in the wild is challenging because of both the limitations and cost of existing smart devices as well as the small study samples sizes. However, there are important lessons learned for future studies.

## RECOMMENDATIONS FOR FURTHER STUDY

While our experiment contains a small sample, it sets out an important protocol on which others can build. Whilst there is a need for replication to demonstrate consistency in findings, environmental interventions on mood have been shown in far more dramatic experimental settings [e.g., after a centrifuge run (Biernacki et al., 2012)]. We believe that—even in small numbers—the experimental design warrants replication to study the effects of short-term tactical interventions on health outcomes and patterns of behavior and can help inform longer-term urban design strategies for public health gains in a community.

We recommend that future experimental designs in this field explore the effects of individual variables, such as personality traits, on well-being outcomes. Basal tense arousal (perceived stress) has been found to be higher in emotionally reactive people (Jankowski and Zajenkowski, 2012), in people with lower emotional intelligence (Stolarski et al., 2016) and prone to neuroticism (Zajenkowska et al., 2015). In addition, positive well-being outcomes from exposure to nature are potentially higher for people with higher trait impulsivity (in turn associated with a higher risk of developing a mental health issue; Bakolis et al., 2018). Also understanding how mood responds to time and seasonality also needs to be better understood. Some mood studies have demonstrated sensitivity to time-of-day effects. Perceived stress (as captured by tense arousal) is especially heightened in evening-oriented people during morning hours (Jankowski and Zajenkowski, 2016). Evening-orientated people, in turn, vary by age: adolescents, for example, are orientated to the evening (Vollmer et al., 2017); older people, to the mornings. In turn, better understanding these orientations, can help better target walking strategies and other public health interventions using blue space and nature settings to specific age groups. Understanding the nuances of these orientations by age and personality, and their effect on well-being outcomes is an important area of future research for the field.

## CONCLUSION

Our findings show that brief exposure to an urban waterfront can positively improve stress, perceived restoration and social well-being, even in a setting where only minor design modifications have been made to increase comfort (i.e., by providing shade and seating) and engagement with the setting (i.e., by increasing fascination). However, we cannot assume a uniformly restorative effect of exposure to urban waterfronts, since exposure to our control condition generated negative effects to perceived stress and arousal. This is the first study, as far as we know, to measure the physiological response to exposure to a waterfront environment; changes in our physiological measure of stress (HRV) corresponded with the changes in our psychological measure of stress, showing a positive effect of exposure to a tactical urban waterfront intervention, albeit only significant at the 0.055 level. Our research, for the first time, found associations between human well-being, tactical urbanism methods and restorative environment theory. These findings have important implications for guiding the direction of longer-term design changes in the environment for public health outcomes.

## AUTHOR CONTRIBUTIONS

JR conceptualized the study design, carried out the fieldwork, oversaw the data analysis, and led the writing of the manuscript with input from co-authors. LB and NN led the methods and analyses for the real-time stress data capture. JT assisted with the design protocol, fieldwork, subjective data analysis, and the literature review for this study.

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