How Does Travel Environment Affect Mood? A Study Using Geographic Ecological Momentary Assessment in the UK

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Abstract

Daily travel is a large part of life, and it is widely believed that our mood can be affected by the environment in which travel takes place. In this study, we investigate how environmental factors affect mood while performing daily travel activities using an app-based geographic ecological momentary assessment study. Our study (the WorkAndHome study) involved over 1000 participants tracked using a bespoke GPS mobile phone app in three cities (Birmingham, Leeds, and Brighton and Hove, UK) At the end of trips (i.e., when a stop in the GPS data was detected) we pushed a survey to participants asking them to score their current happiness and stress levels on a 7-point Likert scale. We combined individual GPS data with environmental data on green and blue spaces and weather conditions. We found that green and blue space availability and weather variables, such as daytime, apparent temperature, and visibility, significantly affect our happiness levels at the end of trips. While these weather factors were also significant predictors of stress level, availability of green and blue space was not. The results of this study provide fine-scale evidence from direct surveys about the associations between environment and weather and our moods when performing daily travel activities.

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1 Introduction

It is well documented that a variety of trip attributes; such as mode of transportation [5], the duration of the trips [17], the type of activity [7], and whether we are travelling alone or not, can affect our mood during and following trips. Less is known about how the environment where trips occur influences mood. Previous evidence supports that trips occurring in greenspaces are associated with greater happiness levels [23]. Further, it is believed that the environmental features where we conduct our trips can significantly influence our mood [5]. To study the effect of environmental factors on our mood, we need to capture individuals' immediate experiences during and/or immediately following trips. Geographic ecological momentary assessment (GEMA) therefore represents an ideal method to track real-time data on how individuals feel. Previous studies have successfully employed GEMA methods to investigate human exposure and response of the environment on people using GPS-enabled

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apps on mobile phones [18]. In this study, we use GEMA to collect targeted information on individual mood (happiness and stress) and investigate how mood is associated with environmental factors such as green and blue spaces and weather conditions.

2 Data and Methods

We used the WORKANDHOME dataset [11, 21] comprising mobile-phone based GPS data for 1029 participants in three UK cities (Brighton and Hove, Leeds, and Birmingham). This data were collected in two sampling periods: Oct 2018 to May 2019 (Leeds, Brighton & Hove) and Sep 2019 to Apr 2020 (Birmingham). We tracked each participant's movement (with their consent) and pushed a GEMA survey corresponding to any trip endpoint detected by the app. In the GEMA survey, we asked a set of 6 questions (Table 1), including questions about mood (happiness, stress, and enjoyment) on a 7-point Likert scale. Along with the GPS data and GEMA survey, we collected detailed socio-demographic information on each participant through a telephone-based survey administered prior to installing our mobile phone app. In this study, we incorporated the self-reported variables on gender, age, and having a health issue limiting mobility.

Table 1 GEMA survey questions and their possible responses.

Questions	Responses	Questions	Responses
Where are you?	Work, home, other	How happy are you?	1-7 (the least to the most)
Whom are you with?	Alone, not alone	How stressed are you?	1-7 (the least to the most)
What activity are you involved in?	Work, housework, leisure, eating, other	How much are you enjoying?	1-7 (the least to the most)

Using methods detailed in [11] we derived trips from individual's raw GPS tracking data. In total, we extracted 31743 trips. However, not all trips have a completed GEMA response at the end, and we kept only those trips where the GEMA survey was completed within 1 hour of the trip end time. After filtering out trips with successful surveys, we had a dataset of 8654 trips from 657 different participants. We used Meteorological Office Integrated Data Archive System (MIDAS) data to assign weather attributes to each trip in our study. MIDAS is a comprehensive weather database managed by the UK's national weather service [14, 15]. Here we used hourly data for rainfall and other weather attributes: air temperature, air pressure, wet bulb temperature, wind speed, and horizontal visibility. Previous research has demonstrated that apparent temperature is a useful variable for capturing how human beings experience weather and therefore we calculated the apparent temperature (in Centigrade) [22]. We used the UK Centre for Ecology and Hydrology (UKCEH) land cover dataset to extract information on green and blue spaces [13]. UKCEH uses Sentinel-2 Seasonal Composite Images reflecting the median reflectance for each season. The land cover dataset is comprised of 21 classes of land cover. We merged 11 green-related classes as green space and two blue-related classes as blue space. We calculated the area of green and blue space present in a buffer of 50 meters around each trip's GPS data. The area of green and blue space within each trip was divided by the area of the 50 m buffer to give a numerical proxy (between 0 and 1) for how much of a trip was in areas where green and/or blue space was present. As previous literature has reported [12], transport mode can significantly affect our mood. Following [24] we employed a Fuzzy Logic system to detect the mode of transportation. We used 6 transportation mode categories: walk, run, bike, bus, train, and car. We used four parameters: median speed, standard deviation speed, proximity to bus routes, and proximity to train routes. Incorporating four parameters enabled us to distinguish between modes that are similar in one aspect but different in the other. For example, bus and car might

have the same median speed, but their proximity to bus routes is different; consequently, our fuzzy system differentiates these two from each other. We employed min-max operation (minimum value in each parameter and maximum value between all mode categories) to identify each mode of transportation. To employ public transit in our model, we used the Open Street Map (OSM) dataset to extract train and bus routes of any kind. We used a linear mixed-effect regression model to account for participants having multiple trips as a random effect. We considered two GEMA response variables (happiness and stress) measured on a 7-point Likert scale. Prior to analysing the data, we adjusted each participants GEMA scores for happiness and stress by subtracting the mean response for each individual across all GEMA surveys (including those GEMA surveys not associated with a trip) from each response.

3 Results

More than two third (69%) of GEMA surveys were not associated with a trip. This provides a comprehensive assessment of happiness and stress levels in various contexts. We observe no significant difference in happiness and stress levels between trip and non-trip GEMA surveys responses (Figure 1). The average and standard deviation of happiness levels for trip GEMA surveys are 4.55 and 1.26, and for non-trip GEMA surveys are 4.55 and 1.30. Similarly, the average and standard deviation of stress levels for trip GEMA surveys are 1.47 and 1.58, and for non-trip GEMA surveys are 1.52 and 1.63.

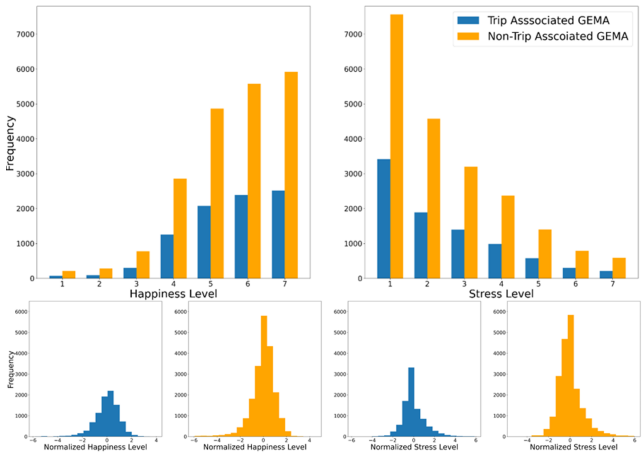

Figure 1 Distributions of raw self-reported happiness and stress levels and their normalized values.

Higher green/blue spaces were found to be positively associated with Happiness scores (Table 2) but showed no significant association with stress level. We found daytime had a negative association with happiness level; meaning individuals had higher happiness scores at night than during the day. Similarly, we found that daytime was positively associated with stress level. Apparent temperature was positively associated with happiness and negatively associated with stress. Rainfall showed no significant association with either of happiness or stress. Travel mode was not found to have an overall significant impact on GEMA happiness or stress scores, with the exception of bus travel, which was negatively associated with happiness (Table 2). Destination type also did not significantly influence observed happiness or stress scores. Trip duration was positively associated with stress level (but not happiness); whereas trip length was negatively associated with stress (but not happiness). Housework, leisure, and other activities were not significantly associated with happiness or stress levels

compared to work as the reference category. Travelling with someone (vs. alone) was not found to be associated with happiness or stress. We found no associations between individual factors (age, gender, whether or not individuals self-report a health issue that limits mobility) and happiness or stress.

Table 2 Results of linear mixed-effect regression models of happiness and stress level.

	Happiness		**Stress**	
Predictors	**Estimates**	**p**	**Estimates**	**p**
(Intercept)	-0.27	0.177	0.17	0.445
Green-Blue Spaces	0.40	**0.032**	-0.20	0.317
Daytime	-0.26	**<0.001**	0.23	**<0.001**
Apparent Temperature	0.24	**0.006**	-0.21	**0.030**
Visibility	0.43	**<0.001**	-0.22	**0.021**
Rain	0.02	0.508	-0.05	0.154
Travel Mode - Walk	-0.01	0.840	-0.08	0.124
Travel Mode - Run	0.07	0.593	-0.12	0.378
Travel Mode - Bike	-0.00	0.951	-0.06	0.465
Travel Mode - Bus	-0.17	**0.020**	0.10	0.200
Travel Mode - Train	-0.20	0.376	0.21	0.411
Travel Mode - Car	-0.08	0.067	0.02	0.718
Destination Type [RC: Home]				
Work	0.02	0.679	-0.04	0.281
Other	-0.02	0.568	0.01	0.798
Duration	-0.43	0.072	0.57	**0.030**
Length	0.23	0.336	-0.55	**0.034**
Activity Type [RC: Work]				
Housework	0.05	0.329	0.00	0.957
Leisure	0.02	0.598	0.05	0.144
Eating	-0.36	0.058	0.16	0.445
Other	0.12	0.447	-0.18	0.283
Presence of People - Not Alone [RC: Alone]	-0.03	0.254	-0.00	0.961
Health and Mobility Issue - Yes [RC: No]	-0.03	0.676	0.08	0.259
Gender - Male [RC: Female]	-0.00	0.995	0.00	0.989
Age [RC: 18-24]				
25-34	0.04	0.433	-0.08	0.152
35-44	0.02	0.703	-0.08	0.150
45-54	-0.02	0.716	-0.04	0.525
55-64	-0.01	0.804	-0.02	0.762
$\sigma 2$	0.98		1.18	
$\tau 00$	0.01		0.02	
Marginal R2 / Conditional R2	0.022/0.034		0.014/0.028	

RC: Reference Category. Bold number: significant association.

4 Discussion and Conclusion

In line with the existing literature, we incorporated environmental and weather factors into our study, as they have been commonly studied in relation to self-reported happiness and stress levels during and after trips. While previous studies have demonstrated that spending

time in green and blue spaces may reduce stress levels [4], we found that daily travel through these spaces is not significantly associated with individuals' stress levels. An important difference in our study is that we are measuring the proportion of the trip through green-blue spaces by area rather than measuring time spent in those spaces, which may differentiate what we have found with previous studies. It is interesting that our results support a positive association between the amount of green-blue spaces experienced during trips and happiness levels, which is a similar effect as to when individuals spend time in these spaces [10].

We found daytime was negatively associated with happiness level and positively associated with stress level. One reason for this might be that it is estimated that 96% of workers are daytime workers [1], and as work is recognized as a significant source of stress [2], it is not unexpected to find daytime a positive predictor of stress level. Similarly we found a positive association between apparent temperature and happiness, but a negative association with stress. Previous studies have found that individuals spend more time on leisure and fun activities [9], and have a better mood [8] during warmer days and seasons which might explain this relationship. We also found horizontal visibility to have the same relationships with happiness and stress, respectively. It has been previously identified that foggy weather and a high level of humidity can negatively affect individuals' moods [25]. Moreover, another reason for this might be that individuals feel safer travelling when visibility is greater.

It is also interesting that we found all transport modes to be non-significant predictors of happiness and stress, with the exception of travel by bus which was negatively associated with happiness. Previous research has reported active transportation and private transportation may positively affect our mood [6]. We limited evidence on the impact of these individual factors, while previous studies have identified significant associations between individual factors and mood during trips [20].

It is worth noting that mood is a complex response which is difficult to capture in survey data, and therefore often difficult to measure [19]. In our study, we limited our analysis to investigating the role of daily travel and the surrounding environment (i.e., weather and green/blue spaces) on individuals' moods. Numerous factors, including individual genetics and personal characteristics [3], and interpersonal connections [16] can affect individuals' moods. We tried to control for this by adjusting the happiness and stress levels by individuals' average scores. However, there are many other varying factors that we cannot control for. Therefore, it is likely that the complexity of individual happiness and stress levels may limit the explanatory power of our models (as observed here, overall model fit was low ($R^2 < 5$ %).

In conclusion, we found that travel environment (such as the presence of green and blue spaces and weather characteristics) was significantly associated with mood (happiness and stress). These results highlight the importance of green and blue spaces in our travel environment. Increasing green and blue spaces along travel routes, especially in urban spaces, can potentially improve citizens' travel-related well-being.

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