Daily Activity Duration Tolerance: A Sensitivity Analysis of Emotional Well-being to Activity Duration

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ABSTRACT

This study introduces "Daily Activity Duration Tolerance" as the duration whereby affective well-being (i.e., happy, tired, stress, sad, pain) deteriorates as a function of activity- and individual-level factors. A panel survival analysis is conducted on 9,618 activity episodes performed by 353 residents of the Minneapolis-St. Paul metropolitan area from October 17, 2016, to October 25, 2017. The analysis examines the responsiveness of affective well-being to activity duration and indicates that negative emotions are tolerated for longer activity duration than the positive emotion of happiness. The findings indicate that activity duration tolerance is shorter for primary activities of shopping, personal business, and eating out than education, work, and leisure. The findings also indicate participation in secondary activities (e.g., religion, caring, and gardening), companionship (e.g., spouse, family, friend, coworkers), and satisfaction with the environment leads to tolerating longer activity durations. The results further show that the chance of happiness worsening is lower for African Americans with similar activity durations than individuals of other ethnic backgrounds, and they tolerate a longer activity duration before their happiness worsens. This knowledge is practical in devising policies that target maximizing positive emotions and minimizing negative emotions.

Keywords: Affective Well-being; Daily Activity; Duration; Threshold Satisfaction.

INTRODUCTION

The ubiquity and duration of daily activities undoubtedly influence the affective well-being of individuals (Raveau et al., 2016). Considering the significance of time, the influence of activity duration on the feelings of individuals has a long standing as a staple for determining the affective state. Specifically, understanding how the positive effect is maximized and the negative effect is minimized as a function of activity duration. Research has started exploring emotions people experience when traveling, with Anable and Gatersleben (2005) as the first researchers in efforts to analyze experienced emotions during travel in detail. They found commuting trips are mostly relaxing and free of stress but not very exciting. However, affective experiences differed according to the chosen mode, as active trips are perceived as more relaxing and less stressful than trips by car or public transport.

The number of travel satisfaction studies mainly increased after the development of the Satisfaction with Travel Scale (STS) (De Vos et al., 2015; Ettema et al., 2011). Since 2010, studies have often used the STS and explored the determinants of travel satisfaction, focusing on travel mode choice and the travel duration. Much of the previous research has found that the use of active travel modes (i.e., walking and cycling) results in the highest levels of travel satisfaction, while public transport use is mostly the least satisfying (De Vos et al., 2016;). A few studies, however, found higher satisfaction levels of public transport users, especially rail-based public transport, compared to car users (Smith, 2017). In addition to travel mode, many studies also explored the effects of travel duration on travel satisfaction and unanimously found a negative effect of duration on satisfaction, meaning the longer a trip takes, the less satisfied travelers will be (Zhu and Fan, 2018). Despite some studies finding a linear negative effect of duration on travel satisfaction (e.g., De Vos et al., 2022), other studies have found a non-linear effect (e.g., Ermagun et al., 2022; Milakis and van Wee, 2018). The non-linear effect believers suggest that satisfaction levels may only start to decrease once a person's ideal, acceptable, or tolerable travel time has been exceeded.

Travel toward out-of-home activities may also affect the experienced emotions during these activities. Bergstad et al. (2011) found a positive correlation between satisfaction with daily travel and satisfaction with activities, while Abou-Zeid and Ben-Akiva (2011) found that commute satisfaction positively affects job satisfaction. Morris and Zhou (2018) observed that longer commute durations –mostly perceived as least positive – are associated with lower work satisfaction. De Vos (2019) found that satisfaction with out-of-home leisure activities is positively affected by satisfaction with the trip to reach that activity. Overall, studies suggest that satisfaction with out-of-home activities is positively

affected by satisfaction with the trip toward that activity. This has been confirmed by Friman et al. (2017), indicating that people's mood during travel lingers during the activity after the trip.

In addition to examining the nexus of travel mode and satisfaction, some studies found that elements such as working conditions, relationships with co-workers, and manager's support can impact job satisfaction (e.g., Aziri, 2011), while the type of leisure activity and companionship can impact satisfaction with leisure activities. However, studies analyzing the determinants of activity satisfaction are limited. Like travel satisfaction, activity duration may have a negative impact on activity satisfaction. This negative impact may also be non-linear. It means people may have a tolerable activity duration. Once this ideal, acceptable, or tolerable activity duration has been exceeded, a reduction in satisfaction levels may be observed.

We explore a dimension of travel behavior in relation to activity duration and well-being. by modeling the effects of activity- and individual-level characteristics on the tolerable daily activity duration that affects individuals' responses to affective well-being, resulting in a decline in emotions. Our contribution is twofold. First, we introduce "Daily Activity Duration Tolerance" (DADT) as the duration whereby affective well-being declines as a function of activity- and individual-level characteristics. Using a total of 9,618 activity episodes performed by 353 residents of the Minneapolis-St. Paul metropolitan area, we employ panel survival analysis to examine the responsiveness of affective well-being to activity duration. Second, we determine how and to what extent activity- and individual-level characteristics lead to acceleration or deceleration of DADT. Here, the intent is not to ascribe a value to DADT. Rather, we simply theorize that DADT is a consequence of activity-level characteristics, which vary across individual-level characteristics.

The remaining structure of this paper is in accordance with the following. First, we review past studies on the relationship between daily activities, activity duration, and subjective well-being. Second, we conceptualize daily activity duration tolerance using hypothetical scenarios to explain individuals' variation in responses to daily activities. Third, we present details on the process of survey and data collection that encompasses the data collection method, the area under study, observations, description of data, and limitations of data. Fourth, the modeling technique is presented. Fifth, we analyze the model estimates of the panel survival analysis. Lastly, we discuss the study's outcome, policy implications, and study limitations.

LITERATURE REVIEW

Research efforts assessed well-being as aggregate measures that comprised life satisfaction Morris, 2015) as well as cognitive well-being (CWB) and affective well-being (AWB) (De Vos, 2019; Ettema et al., 2011). In an attempt to understand disaggregate level responses to activities, researchers assessed both positive and negative affect. Positive well-being responses comprised of happiness (Mokhtarian and Pendyala, 2018;) and pleasantness (Ravulaparthy et al., 2017). Negative well-being responses included stress, tiredness, , fatigue, , sadness, worry, and pain (Mokhtarian et al., 2015; Ravulaparthy et al., 2017; Zhu and Fan, 2018). Research was also conducted on the specific meaningfulness of emotion pertaining to the cognitive well-being (Pendyala et al., 2018). Well-being responses to activity duration were assessed in approximately half of the studies.

Bergstad et al. (2011) studied residents of Sweden's responses to life satisfaction, CWB, and AWB for nine daily activities. The results showed a positive correlation between satisfaction with out-of-home activities and weekly mood, AWB, and CWB. Also, in Sweden, Ettema et al. (2011) established and examined satisfaction with travel scale (STS) as a gauge of well-being. This measure was assessed by surveying undergraduate students at Karlstad University to determine their responses to away-from-home activities comprising of three unique agenda items: Agenda 1 (Work + dropping off/picking up a child at daycare), Agenda 2 (Agenda 1 + grocery shopping), and Agenda 3 (Agenda 1 + durable shopping in a department store). Results showed AWB responses dropped with participation in more activities, and the mood was highest in response to Agenda 1 with the fewest activities. Bergstad et al. (2012) researched the magnitude of the effect associated with out-of-home activities, directly and indirectly, influencing CWB via mood as the mediator. Although the study outcome revealed that the average affect ratings of activities positively correlated with AWB and CWB, the effect associated with out-of-home activities was larger in association with AWB. Archer et al. (2013) examined the link between activity-travel patterns and CWB and AWB. Individuals exhibited higher happiness levels when participating in in-home and out-of-home activities, social interactions out-of-home, and religious observation with children. Individuals experienced a drop in happiness for work, volunteer, and religious observations out-of-home. Ravulaparthy et al. (2013) examination of the elderly resulted in increased happiness levels, which stemmed from frequent engagement in physical activities (i.e., sports, workout, exercise, walking), leisure, and social activities. In the absence of these events, a decline in happiness levels was reported.

In Santa Barbara, California, Deutsch-Burgner et al. (2014) surveyed 561 respondents and discovered an association between high happiness levels and participation in eating out and outdoor recreation,

with low happiness levels associated with activities with family members and shopping. Mokhtarian et al. (2015) examined pleasurable and fatiguing trip experiences of 13,072 respondents who reported work increased their likelihood of unpleasantness and physical and mental fatigue. Morris (2015) evaluated the link between travel, out-of-home activities, and life satisfaction of 21,750 residents and deduced that out-of-home activities increased the likelihood of life satisfaction. In a transnational study by Raveau et al. (2016), work and education abated happiness levels, and travel destination activities magnified happiness levels. De Voss study (2019) in Ghent, Belgium showed that leisure activities positively impacted happiness while cultural or sports activities negatively impacted mood. Based on 4,329 activity episodes by 394 elderly couples, Ravulaparthy et al. (2017) concluded that out-of-home activities increased the likelihood of gaining happiness, pleasantness, and calmness. Research outcomes by Pendyala et al. (2018) showed a strong correlation between out-of-home activities, positive AWB, and CWB. Mokhtarian and Pendyala (2018) found that respondents expressed the highest happiness when conducting out-of-home discretionary activities and the lowest happiness levels associated with in-home activities not involving online shopping. Zhu and Fan's study (2018) showed that discretionary leisure, exercise, and community activities were mostly associated with elevated levels of happiness, while reduced levels of negative emotions were linked to mandatory work and home trip purposes. A study by De Vos (2019) showed that activities such as eating out, sports, exercise, outdoor, arts, entertainment, volunteering, and religion resulted in positive life satisfaction.

Specific to the emotional responses to activity duration, Archer et al. (2013) discovered that activity duration influenced happiness when conducting maintenance and social activities. Ravulaparthy et al. (2013) showed that more time spent on physical activities reduced the level of happiness of respondents. Raveau et al. (2016) determined that longer work and education activities negatively impacted happiness. Pendyala et al. (2018) examined individuals preferred shorter durations of in-home activities, up to 4 hours led to a higher likelihood of better well-being.

Progress has been made in advancing the research on subjective well-being responses to daily activities and activity duration. The literature review, however, is not void of gaps. First, a limited number of studies assess the contributions of activity- and individual-level characteristics on activity duration, which results in the decline of cognitive and affective well-being. Second, the present research is confined in scope to the range of emotions examined and the activity- and individual-level characteristics. Third, most studies gathered data using paper-based, web-based, or computer-assisted

phone interviews. The adoption of real-time tracking of activity episodes and well-being is an avenue to collect and process data automatically. Specific to our study, we employ the Daynamica smartphone application to examine the duration where well-being declines due to activity- and individual-level characteristics. We are also in a quest to evaluate how the activity- and individual-level characteristics accelerate or decelerate the decline of well-being.

DAILY ACTIVITY DURATION TOLERANCE CONCEPT

Daily Activity Duration Tolerance is the time to an affective well-being decline while embarking in an activity. The level of affective well-being at the start of the activity is the level of affective well-being at the end of the previous trip. It decreases, remains the same, or increases at the end of the activity, albeit it might fluctuate during the activity. The change in the level of affective well-being is a function of activity- and individual-level characteristics. Figure 1 illustrates it by visualizing the activity pattern of James in a weekday. His hypothetical home-based tour includes three out-of-home activities of work, eating out, and shopping with sequences, travel modes, and accompaniment characteristics. James takes public transit alone and arrives at work at t_1 with the level of happiness of 3 out of 7 Likert score. His work ends at t_2 with a reported level of happiness of 1. Time t_1 to t_2 is the DADT of happiness for James, in which his AWB worsens from the level of happiness of 3 to the level of happiness of 1 participating in a work alone. He continues his tour by biking to a restaurant where his spouse reserved a table and arrives at t_3. His level of happiness increases due to his bike trip and he starts his eating out activity with the level of happiness of 2. His eating out accompanied with his spouse and co-worker ends at t_4 with a reported level of happiness of 6 out of 7. He experienced an increase in his level of happiness due to his eating out activity with accompaniment. Jill and James drive to a grocery store and arrive at t_5. James experienced no change in his level of happiness due to his trip and starts shopping with the level of happiness of 6. His level of happiness drops at the end of the shopping and he reported the level of happiness of 4 out of 7. Time t_5 to t_6 is the DADT of happiness for James, in which his AWB worsens from the level of happiness of 6 to the level of happiness of 4 participating in a shopping activity with Jill.

This is evidence that the activity- and individual-level characteristics influence daily activity duration tolerance. The worsening of affective well-being responses is justified by the circumstances of age, race, primary activities, secondary activities, time of the day, travel mode to activity, and companionship. If James embarked eating out and shopping alone, he might have become less happy at the end of his eating out or tolerated shorter shopping duration and ended it sooner. In the following, we test the activity- and individual-level correlates of DADT.

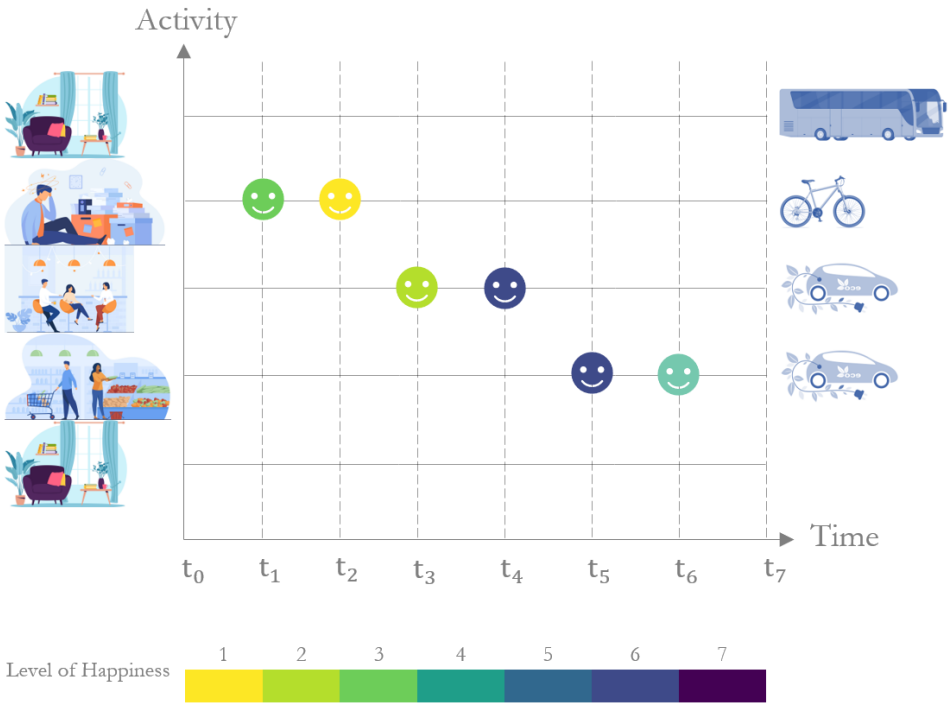


FIGURE 1 Illustration of Daily Activity Duration Tolerance (DADT) and well-being responses to activities

SURVEY AND DATA COLLECTION

Data Collection

The Daynamica smartphone application was employed in the Minneapolis-St. Paul Metropolitan area to collect the travel diary of residents from six neighborhoods (i.e., Blaine, Brooklyn Center, Near North, Phillips, Prospect Park, St. Anthony Park) for seven consecutive days between October 17, 2016, and October 25, 2017. The application collected ordered sequence of activity and trip episodes containing (i) spatial attributes (e.g., start and end location, GPS trajectory as an ordered sequence of latitudes and longitudes), (ii) temporal attributes (e.g., start and end times), and (iii) thematic attributes (e.g., primary activity type, secondary activity type, travel mode). Daynamica also allowed participants to annotate thematic attributes with additional information including emotional well-being experiences. Incorporated in Daynamica is the concept of the Day Reconstruction Method (DRM). DRM "assesses how people spend their time and how they experience the activities and setting of

their lives" by asking participants to "systematically reconstruct their activities and experiences" (Miret, 2012) through a structured, self-administered questionnaire. The DRM builds on the strengths of time-budget measurement and experience sampling while employing techniques established in cognitive science. Benefits of this approach include lowering the burden of typical sampling methods for both the respondent and researcher, providing more coverage of the participant's day compared to a typical experience sampling method, and actively reducing the susceptibility to retrospective biases (Kahneman, 2004). Miret et al. (2012) asked participants to reconstruct their activities and experiences by reporting emotions associated with positive and negative feelings. Their research concluded that DRM had a significant advantage of reducing memory and judgmental biases, decreasing completion time, and increasing ease of use compared to other questionnaire methods. Daynamica plays with the idea of the Digital Day Reconstruction Method (DDRM). The goal and presentation are the same as traditional DRM, but the collection takes place digitally through a smartphone, allowing participants to report their satisfaction instantly in real-time through a click of a button.

Recruitment of participants was premised on geographic cluster sampling, where random blocks were selected within six neighborhoods, with as many households as possible from each random block. Information gathered from the smartphone application included activity- and individual-level characteristics that ordered the day of each participant into activity episodes based on the automatic tracking and discerning of trips in real-time. Participants self-reported their AWB experienced (i.e., happy, tired, stress, sad, pain) during the activity at the end of the activity episode on a Likert-type scale from 1 to 7. A value of 1 is indicative that respondents did not experience happiness, tiredness, stress, sadness, or pain, and 7 is indicative that the feeling of happiness, tiredness, stress, sadness, or pain was extremely strong. Participants were allowed to annotate the detected activity with additional information such as secondary activities, physical activity, companionship, and satisfaction with the environment. Participants were also allowed to adjust activity start and end time and correct the primary activity and travel mode. Although participants are notified by Daynamica to complete a built-in survey at the end of each activity episode, they are allowed to self-report their AWB experience at their convenience. The time of fulfilling additional information, of course, might affect the accuracy of AWB as the feelings reported at the end of the day might not be as accurate as the momentary feelings. However, there is no information to distinguish AWB responses retrospectively reported at the end of the day from momentary AWB.

Data Preparation

The raw data contained 25,698 episodes for 372 participants, of which 12,877 were activity episodes and 12,821 were trip episodes. The Daynamica technical team conducted post-processing steps to detect (i) attribute incompleteness and (ii) logical inconsistency due to GPS data collection challenges. Technical challenges include (i) limited sampling frequency, (ii) warm or cold start of devices, (iii) satellite signal interference, (iv) mislabeled trips or activities due to the computational algorithms, and (v) inaccurate user-verified information. Invalid episodes include: (i) episodes containing incomplete spatial, temporal, or thematic attributes, (ii) consecutive episodes with no continuity in space (i.e., a longer Euclidian distance than 16ft between the locations of two consecutive episodes) or time (i.e., inequality between the end time and start times of two consecutive episodes), (iii) episodes with start time greater than end time, (iv) unrealistic episodes with the average speed greater than 200 mph, and (v) redundant episodes with the same thematic attributes. Overall, attribute incompleteness occurred less frequently than temporal and spatial inconsistencies. Attribute incompleteness ranged from 0.00% for education to 0.36% for leisure, temporal inconsistency ranged from 6.14% for eating out to 22.23% for home, and spatial inconsistency ranged from 21.37% for education to 28.92% for eating out. Zhang et al. (2022) discuss the details of the framework adapted to systematically detect and handle quality issues in the Daynamica smartphone application rather than simply removing invalid episodes to ensure attribute completeness and logical consistency. This yielded to 24,892 episodes for 366 participants, of which 12,818 were activity episodes and 12,074 were trip episodes. The retrieved activity episodes, however, still included missing information related to secondary activities, physical activity, companionship, and satisfaction with the environment. In case of the missing variable, the research team eliminated the observation. This yielded to 11,576 activity episodes for 364 participants.

Data Description

Table 1 provides the descriptive statistics of the sample population. Of the 364 respondents, the mean age is 48. Female respondents make up 64% of the sample. The representation of African Americans in the sample is 8%. A high percentage of the sample population is satisfied with the environment. Car use is the dominant travel mode, followed by walking. Primary activities include (i) home, (ii) work, (iii) education (e.g., daycare, pre-school, grades K-12, college or university, school activities), (iv) personal business (e.g., banking, medical, salon), (v) eating out (e.g., restaurant, drive-thru), (vi) leisure (e.g., visiting friends or relatives, watching movies or sport events, worship, wedding, funeral, sports, exercise, park, museum), and (vii) shopping (e.g., appliances, cars, clothes, grocery, gas). Home activities are associated with the highest percentage (30%), and leisure scores the highest percentage (16%) of out-of-home activities. Respondents conducted activities more frequently with their spouses and with children and with less frequency with their co-workers. Secondary activity associated with caring for others makes up 16% of the sample, and the other secondary activities (i.e., volunteering,

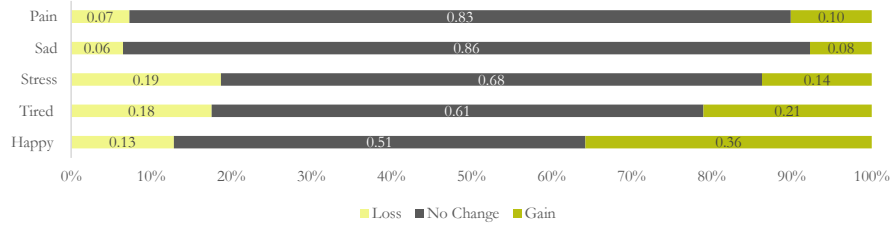
community events, religious, gardening) have very low participation rates. The preferred activity time is in the evening (27%), with midnight activities constituting a very low percentage (4%).

TABLE 1 Descriptive of the variables used in the analysis

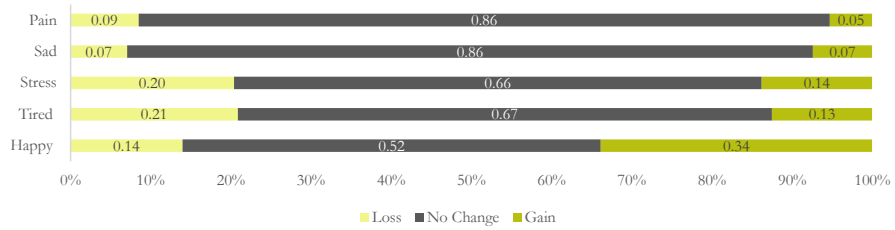
Variable	Description	Average	St. Dev
	Activity-Level Factors		
Travel Mode			
RAIL	1: If the travel mode to activity is rail; 0: Otherwise	0.01	0.10
BUS	1: If the travel mode to activity is bus; 0: Otherwise	0.03	0.19
BIKE	1: If the travel mode to activity is biking; 0: Otherwise	0.04	0.19
WALK	1: If the travel mode to activity is walking; 0: Otherwise	0.19	0.39
CAR	1: If the travel mode to activity is car; 0: Otherwise	0.62	0.48
Primary Activities			
HOME	1: If the purpose of the trip is home; 0: Otherwise	0.30	0.45
LEISURE	1: If the purpose of the trip is leisure; 0: Otherwise	0.16	0.37
EATING OUT	1: If the purpose of the trip is eating out; 0: Otherwise	0.06	0.24
EDUCATION	1: If the purpose of the trip is education; 0: Otherwise	0.03	0.17
PERSONAL	1: If the purpose of the trip is personal business; 0: Otherwise	0.14	0.35
WORK	1: If the purpose of the trip is work; 0: Otherwise	0.14	0.35
SHOP	1: If the purpose of the trip is shopping; 0: Otherwise	0.14	0.34
Activity Companion			
SPOUSE	1: If the traveler is accompanied by spouse; 0: Otherwise	0.24	0.43
FAMILY	1: If the traveler is accompanied by family; 0: Otherwise	0.11	0.32
CHILDREN	1: If the traveler is accompanied by children; 0: Otherwise	0.16	0.37
WORKPEOP	1: If the traveler is accompanied by coworkers; 0: Otherwise	0.10	0.30
FRIENDS	1: If the traveler is accompanied by friends; 0: Otherwise	0.18	0.38
Secondary Activities			
VOLUNTEERING	1: If the activity involves volunteering; 0: Otherwise	0.02	0.16
COMMUNITY EVENTS	1: If the activity involves community events; 0: Otherwise	0.03	0.19
RELIGIOUS	1: If the activity involves religious events; 0: Otherwise	0.02	0.16
CARING	1: If the activity involves caring; 0: Otherwise	0.16	0.36
GARDENING	1: If the activity involves gardening; 0: Otherwise	0.02	0.16
PHYSICAL	1: If the activity involves moderate or vigorous physical activity; 0: Otherwise	0.24	0.43
Time of the Day			
MORNING	1: If the arrival time to the activity is between 6:00 AM and 10:59 AM	0.22	0.41
MIDDAY	1: If the arrival time to the activity is between 11:00 AM and 13:59 PM	0.22	0.41
AFTERNOON	1: If the arrival time to the activity is between 14:00 PM and 16:59 PM	0.23	0.42
EVENING	1: If the arrival time to the activity is between 17:00 PM and 21:59 PM	0.27	0.44
MIDNIGHT	1: If the arrival time to the activity is between 22:00 PM and 5:59 AM	0.04	0.20
Satisfaction with Environment			
ENVIRONMENT SATISFACTION	1: If the traveler is satisfied by the environment; 0: Otherwise	0.78	0.40
Initial Affective Well-being (AWB)			
HAPPY	Traveler's happiness at the beginning of the activity on a 7-point Likert scale	4.94	1.51
TIRED	Traveler's tiredness at the beginning of the activity on a 7-point Likert scale	2.67	1.70
STRESS	Traveler's stress at the beginning of the activity on a 7-point Likert scale	2.10	1.45
SAD	Traveler's sadness at the beginning of the activity on a 7-point Likert scale	1.44	1.06
PAIN	Traveler's pain at the beginning of the activity on a 7-point Likert scale	1.62	1.22
	Individual-Level Factors		
FEMALE	1: If the traveler is female; 0: Otherwise	0.64	0.48
AGE	The age of the traveler	49.35	15.9
BLACK	1: If the traveler is African-American; 0: Otherwise	0.08	0.28

Figure 2 reveals the frequency distribution for AWB responses of each primary activity represented in three categories—loss, no change, and gain. The change in well-being (loss or gain) is the difference in participants' well-being responses at the start and end of the activity. Of the negative AWB responses, tiredness and stress experience a greater change than pain and sad in response to daily activities. The most gain of tiredness is attributed to home (34%) and leisure (21%). Participants report that eating out, education, personal business, work, and shopping produce stress. Work results in the most stress gain (33%), followed by education (27%), personal business (18%), shopping (15%), and eating out (14%). For the positive AWB response of happiness, leisure produces the most happiness gain at 36%. This is followed by eating out (34%), home (31%), and education (30%). The least happiness gain is attributed to shopping (19%).

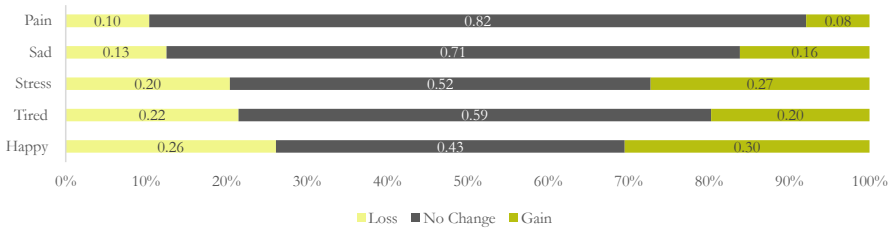
a. Home



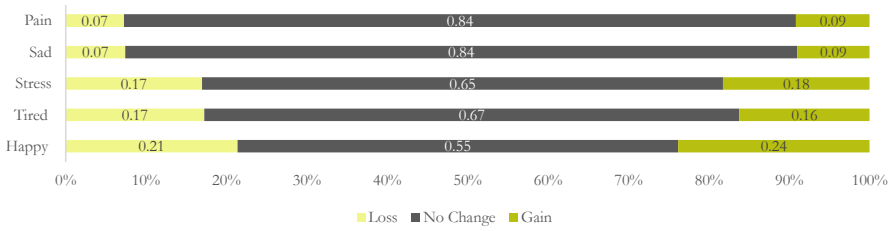
b. Leisure and Recreation



c. Eating out

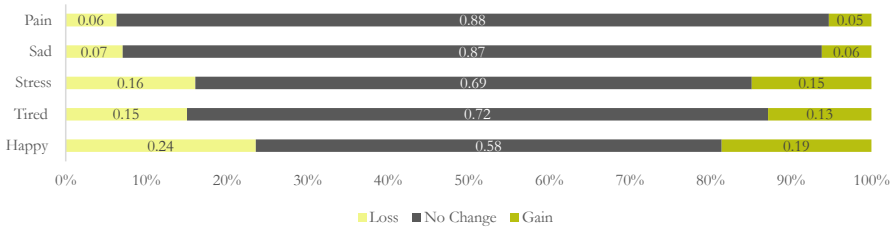


d. Education



e. Personal Business

f. Work



g. Shop

FIGURE 2 Change in well-being responses as a function of daily activities

Data Limitations

One limitation of our dataset is the presence of incomplete information about the DADT of some participants. We are interested in AWB becoming worse in the time period between the beginning and the end of an activity. The impossibility of participants to report their minute-by-minute AWB while conducting an activity, however, leaves us with the self-report of AWB solely at the beginning and the end of an activity. This emerges two censorships. First, the AWB at the end of the activity is worse than at the beginning of the activity, but the exact worsening time is unknown. It happens when the participant experienced the AWB worsening earlier than the end of the activity. The DADT is then shorter than what we captured in our data. Second, the AWB endures no worsening in the time period between the beginning and the end of an activity. It occurs when the participant has not yet experienced the AWB worsening. The DADT is then longer than what we captured in our data. An example suffices. A participant is observed to tolerate a shopping duration without her happiness becomes worse. She, however, might have tolerated a longer shopping duration if the time period was not limited to the beginning and the end of shopping. This is often called right censoring as the true unobserved AWB worsening is to the right of the censoring time. A participant is observed to not tolerate a shopping duration and her happiness becomes worse at the end of shopping. Her tolerable shopping duration, however, might be shorter as she might have experienced happiness worsening earlier than the end of shopping. This is often called left censoring as the exact time of AWB worsening is concealed and all we know is DADT is less than the activity duration. The censorship associated with our data is noninformative as participants were not censored due to their lower or higher risk of AWB worsening.

Another limitation of our dataset is the range of Likert scale used for measuring the AWB dimension. This might lead to a censorship as participants have no choice to indicate whether they felt worst at the end of their activity compared with the beginning of their activity if they choose the worst score of AWB at the beginning of an activity. This limitation has fortunately not affected our analysis as the share of instances with the worst score of AWB at the beginning and end of an activity is marginal. It equals 1.9%, 2.5%, 1.0%, 0.7%, and 0.6% for self-report happiness, tiredness, stress, sadness, and pain, respectively. Future research might avoid it by accompanying a question asking whether participants feel worse at the end of the activity compared to the beginning of the activity.

METHODOLOGY AND MODELING

Survival Analysis

Time to event analysis has been used in the transport literature where interest is on analyzing time to events such as truck stop durations, time to evacuate, and time to shipment delivery. Censoring and non-normality aspects of time to event data generate difficulty to employ traditional multiple linear regression models and popularity to develop survival or failure time analysis. Survival analysis measures the time to an event as well as the hazard rate. In survival-time data, each observation indicates a time span including the start time, the end time, and an indicator of failure or right-censoring at the end of the time span. We applied the hazard-based duration model, also known as survival analysis, to study time-to-event as a function of activity- and individual-level characteristics. Hazard-based models are characterized in terms of hazard function $h(t)$ or survival function $S(t)$, whereby $h(t)$ is the instantaneous potential per unit time for the event to occur, given that the individual has survived up to time t and $S(t)$ is the probability of the duration being at least t (Washington et al., 2003). Both $h(t)$ and $S(t)$ describe the duration process. Equation (1) depicts the hazard function, and Equation (2) represents the survival function.

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t + \Delta t \geq T \geq t)}{\Delta t} \quad (1)$$

$$S(t) = \mathrm{P}(T \geq t) \quad (2)$$

Survival analysis is categorized into three methods – parametric, non-parametric, and semi-parametric. We adopt parametric modeling to specify the survival and hazard functions, specifically using the Weibull functional form determined in the modeling process to be the best fit. This is done by selecting the lowest Akaike Information Criterion (AIC) value (Akaike, 1974) based on comparing the various parametric distributions. To visualize the shape of $h(t)$ and $S(t)$, Kaplan-Meier (KM) estimator curves is employed. The KM estimator measures the survival time and is used in determining the survival probability. The KM estimator $S_{KM}(t_j)$ estimates the survival function via the use of Equation (3) where n_j is the number of observations at risk for each duration at time j and d_j is the number of events at time j.

$$S_{KM}(t_j) = \prod \frac{n_j - d_j}{n_j} \quad (3)$$

Hazard Ratio and Acceleration Factor

Hazard ratio (HR), which measures the effect of the survival analysis estimating the ratio of hazards between two groups, is reported in the parametric model. The Weibull model outputs both the coefficient and HR, with HR computed by taking the exponent of the coefficients (β). This is mathematically represented in Equation 4 and interpreted as $HR > 1$ or $HR < 1$.

$$HR = e^{\beta} \quad (4)$$

Accelerated failure time (AFT) shows the influence of independent variables on the hazard function by the acceleration or deceleration of survival time. Acceleration factor (AF), a measure of the AFT model, evaluates the covariates on the survival time. AF is computed per Equation 5.

$$AF = e^{(\frac{-\beta}{p})} \quad (5)$$

The shape function, p, determines the shape of the hazard function. $p > 1$, $p < 1$, and $p = 0$ are indicative of increasing hazard, decreasing hazard, and constant hazard over time (Kleinbaum and Klein, 2012). Five separate Weibull models were generated for each AWB response -- happiness, tiredness, stress, sadness, and pain.

Model Specification

We conduct the panel survival analysis as we have repeated observations on the same individual over time. The primary analysis unit is activities, each panel is an individual, and the observations within

366 panel are activities conducted by individuals. Unlike classic survival models, each individual is
367 associated with more than one time-to-event outcome as (i) individuals might conduct more than one
368 activity type in the course of data collection (e.g., work, shop, leisure) and (ii) individuals might conduct
369 an activity more than one time in the course of data collection (e.g., work on Monday, work on
370 Tuesday). Neither is the time-to-event outcome for two different activities nor the time-to-event
371 outcome for an activity conducted in two different times necessarily identical for an individual. This
372 necessitates controlling for individual heterogeneity. There is also a random effect or an unobserved
373 latent effect for each individual as the same individual reported the time-to-event outcome at two or
374 more points in time and we would not want to assume that time-to-event outcomes within each
375 individual are independent. This necessitates modeling the correlation. Number of groups in Table 2
376 declares the number of panels or individuals. Our modeling approach includes interaction analysis.
377 This is recommended over subgroup analysis and ideally results in the same coefficients. We tested
378 interaction variables between primary activities and other explanatory variables and embedded
379 statistically significant variables with the 90% confidence interval threshold. In our modeling practice,
380 we tried to prioritize embedding interaction variables between primary activities and travel modes.
381 Simply, whenever an interaction variable between primary activities and travel modes becomes highly
382 correlated with another explanatory variables, we priorities travel modes without loss of generality.
383 This, however, happened in a few instances. There is at least one category left out when dummy
384 variables are embedded in the models for estimation purposes. We tested travel modes of rail, bus,
385 bike, walk, and car. There was however no statistically significant correlation between motorized travel
386 modes and the activity duration tolerance.

387 In our model specification, we strived to test all theoretically and practically relevant explanatory
388 variables while being cautious of multicollinearity. The student's t-test statistic is measured to assess
389 the statistically significance of each explanatory variable with the 90% significance level. We adopted
390 the stepwise technique and began with embedding primary activities, travel modes, initial affective
391 well-being, activity companion, secondary activities, satisfaction with environment, time of the day,
392 and individual-level factors. We continued by adding interaction effects between primary activities and
393 other explanatory variables. This helps explore whether the effect of explanatory variables on DADT
394 is different for different primary activities. This approach is recommended over subgroup analysis and
395 ideally results in the same coefficients. While developing models, many variables with theoretical
396 relevance were found statistically insignificant. They include trip duration, motorized travel modes

(i.e., rail, bus, car), community events and volunteering secondary activities, children activity companion, and female. They were found statistically insignificant both in the stepwise process and in a bivariate model with a few exceptions. Testing bivariate analysis, we found that trip duration and transit use result in the tolerance of shorter activity durations before happiness worsens and walking results in the tolerance of shorter activity durations before stress worsens.

Model Interpretation

Hazard ratio and acceleration factor estimates are shown in Table 2. We reported the coefficients and their t-statistics in a separate table documented in the Appendix. The estimates evaluate how and the extent to which DADT changes across a stratum of people. The model outputs show the activity, and individual distinctiveness that affect daily activity duration and changes to positive (happiness) and negative (tiredness, stress, sadness, and pain) affects. The event in this study is the worsening of AWB when the event changes from 0 to 1, with 1 representing the event occurrence. The positive affect (happiness) becomes less, and the negative effects (tiredness, stress, sadness, and pain) worsen. For instance, happy becomes less happy, and tired becomes more tired. All covariates are dummy variables except for AGE which is continuous. From the output of Table 2, the interpretation of the hazard ratios and acceleration factors are as follows:

- Hazard ratio > 1: The likelihood that AWB responses (i.e., happiness, tiredness, stress, sadness, pain) worsen is higher in a similar activity duration.
- Hazard ratio < 1: The likelihood that AWB responses (i.e., happiness, tiredness, stress, sadness, pain) worsen is lower in a similar activity duration.
- Acceleration factor > 1: The AWB responses (i.e., happiness, tiredness, stress, sadness, pain) worsen in longer activity duration.
- Acceleration factor < 1: The AWB responses (i.e., happiness, tiredness, stress, sadness, pain) worsen in a shorter activity duration.

Table 2 Model Estimates of Hazard Ratio and Acceleration Factor

Variables	Hazard Ratio (Acceleration Factor)				
	Model 1 Happy	Model 2 Tired	Model 3 Stress	Model 4 Sad	Model 5 Pain
Activity-Level Characteristics					
WORK	2.363 (0.360)	2.004 (0.517)	3.034 (0.335)	2.140 (0.454)	1.380 (0.710)
EDUCATION	3.281 (0.244)	1.528 (0.669)	2.168 (0.467)	4.909 (0.192)	1.826 (0.528)
LEISURE	2.841 (0.289)	1.568 (0.653)	3.842 (0.266)	3.290 (0.291)	2.930 (0.319)
EATING	11.917 (0.053)	5.562 (0.197)	6.253 (0.165)	5.436 (0.173)	2.228 (0.427)
PERSONAL	9.507 (0.069)	3.074 (0.345)	6.271 (0.164)	4.953 (0.191)	3.995 (0.230)
SHOP	18.430 (0.031)	3.487 (0.306)	8.134 (0.127)	4.938 (0.191)	5.099 (0.177)

WALK	1.189 (0.814)	0.866 (1.146)	-	-	-
BIKE	1.214 (0.794)	-	-	-	-
PHYSICAL	0.764 (1.377)	-	-	-	1.650 (0.588)
SPOUSE	0.593 (1.862)	0.760 (1.298)	0.592 (1.675)	0.622 (1.636)	0.768 (1.323)
FAMILY	0.687 (1.562)	0.690 (1.421)	1.000	1.000	-
WORKPEOP	0.458 (2.528)	0.653 (1.497)	0.760 (1.310)	0.525 (1.951)	-
FRIENDS	0.473 (2.434)	0.657 (1.489)	0.874 (1.142)	0.804 (1.253)	-
RELIGION	0.408 (2.902)	-	0.757 (1.316)	-	-
CARING	0.778 (1.348)	0.864 (1.148)	-	-	0.658 (1.560)
GARDENING	0.687 (1.564)	0.717 (1.370)	0.596 (1.665)	-	-
EVENING	0.690 (1.554)	0.913 (1.090)	0.703 (1.415)	0.825 (1.220)	0.804 (1.260)
MIDNIGHT	0.600 (1.834)	0.866 (1.146)	0.532 (1.863)	0.619 (1.643)	0.633 (1.626)
ENVIRONMENT SATISFACTION	0.434 (2.699)	0.875 (1.134)	0.627 (1.584)	0.649 (1.566)	0.733 (1.390)
WORK_WALK	-	1.502 (0.680)	1.232 (0.814)	-	-
LEISURE_WALK	1.634 (0.558)	1.745 (0.590)	1.699 (0.594)	-	-
EDUCATION_WALK	-	2.504 (0.419)	-	-	-
PERSONAL_WALK	-	-	0.601 (1.650)	-	0.579 (1.787)
WORK_BIKE	-	-	-	1.806 (0.542)	-
LEISURE_BIKE	2.942 (0.277)	-	-	2.282 (0.525)	-
PERSONAL_TRANSIT	0.583 (1.898)	-	-	-	-
SHOP_TRANSIT	0.417 (2.827)	-	-	-	-
WORK_FRIENDS	1.726 (0.522)	1.605 (0.639)	-	-	-
WORK_FAMILY	-	2.721 (0.387)	-	-	-
WORK_SPOUSE	1.614 (0.566)	-	-	-	-
LEISURE_FRIENDS	-	1.659 (0.619)	-	-	-
LEISURE_SPOUSE	-	-	-	-	0.508 (2.052)
LEISURE_WORKPEOP	3.873 (0.200)	-	-	-	-
EDUCATION_SPOUSE	2.743 (0.301)	2.721 (0.387)	2.173 (0.466)	-	-
EATING OUT _FAMILY	0.474 (2.431)	1.000	0.520 (1.904)	-	-
EATING OUT_FRIENDS	0.535 (2.105)	0.502 (1.921)	0.368 (2.678)	-	-
EATING OUT_SPOUSE	-	0.608 (1.603)	-	-	-
EATING OUT_WORKPEOP	-	-	-	4.600 (0.206)	-
PERSONAL_WORKPEOP	-	-	-	-	-
PERSONAL_FAMILY	0.679 (1.584)	-	0.639 (1.554)	-	-
PERSONAL_FRIENDS	-	-	0.639 (1.554)	-	-
SHOP_FAMILY	-	1.813 (0.569)	-	1.718 (0.571)	-
SHOP_SPOUSE	1.381 (0.681)	-	1.570 (0.642)	-	-
SHOP_FRIENDS	-	1.716 (0.599)	-	-	-
LEISURE_ PHYSICAL	-	1.958 (0.529)	-	0.672 (1.510)	1.664 (0.583)
PERSONAL_PHYSACAL	-	-	-	0.499 (2.055)	-
LEISURE_ SATISFY	0.508 (2.237)	-	0.536 (1.848)	-	-
WORK_SATISFY	-	0.745 (1.323)	-	-	-
EATING OUT _SATISFY	-	0.605 (1.611)	-	-	-
EDUCATION_SATISFY	-	-	1.868 (0.541)	2.243 (0.433)	-
INITIAL AWB	1.923 (0.459)	0.699 (1.404)	0.705 (1.410)	0.750 (1.348)	0.763 (1.333)
WORK INITIAL AWB	-	0.914 (1.089)	0.870 (1.147)	-	-
EATING INITIAL AWB	0.859 (1.198)	1.174 (0.859)	1.176 (0.853)	-	1.254 (0.787)
EDUCATION INITIAL AWB	-	-	-	0.583 (1.748)	-
PERSONAL INITIAL AWB	1.087 (0.906)	-	-	-	-
SHOP INITIAL AWB	0.871 (1.178)	1.179 (0.855)	-	1.176 (0.845)	-
Individual-Level Characteristics					
AGE	0.983 (1.020)	0.979 (1.020)	0.978 (1.022)	0.981 (1.020)	0.991 (1.010)
BLACK	0.566 (1.969)	1.297 (0.782)	-	1.896 (0.515)	2.467 (0.383)
Constant	0.00029723	0.00472920	0.00470561	0.00123091	0.00058729
Number of Observations	9,618	9,615	9,618	9,611	9,607

Number of Groups	353	353	353	351	351
Ln (p)	-0.173	0.053	0.016	-0.034	-0.059
p	0.841	1.055	1.016	0.965	0.942

Note: The difference in the number of observations between models is due to the missing self-reported of each AWB experience in our sample.

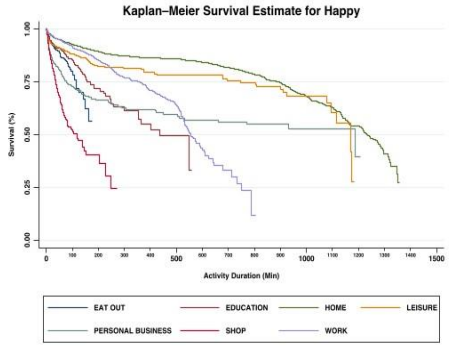
Sample interpretations from Table 2 is herein presented. The hazard ratio and acceleration factor for individuals who bike to activities are 2.07 and 0.41, respectively. This implies that (1) the chance of happiness worsening is higher in a similar activity duration when a bike is the travel mode to activities compared to motorized modes of travel, and (2) activity duration tolerance becomes shorter when biking to activities. Results also indicate that using the bike previous to an activity does not affect the worsening of the negative AWB. The chance of both happiness and tiredness worsening is also higher in a similar activity duration when people have walked instead of used motorized travel. Walking does result in worse levels of stress, sadness or pain.

RESULTS

Here, we analyze DADT using Kaplan-Meier curves, hazard ratio, and acceleration factors and establish the activity and individual characteristics that accelerate and decelerate the positive and negative effects of well-being.

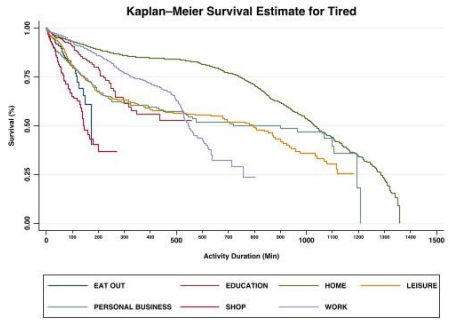
Survival Probability

Results of the KM curves and estimates are depicted in Figures 3(a) to 3(e) for all five emotions under study. Each KM curve is a delineation of the change in DADT for all activities and is indicative of the change in survival probability for the event when affective well-being worsens. And the corresponding KM estimates summarize the activity duration by the failure probability. The event of affective well-being worsening as a function of engaging in daily activities is equivalent to the failure probability. This equals 1 minus survival probability reported in Figure 3.



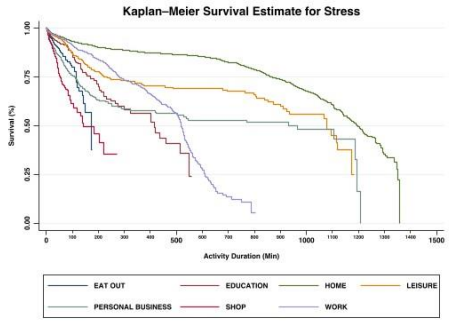
Activities	0%	25%	50%	75%	100%
Eating Out	0	1.9	-	-	-
Education	0	2.8	7.2	-	-
Home	0	14.8	20.5	-	-
Leisure	0	12.4	19.4	-	-
Personal Business	0	1.2	19.7	-	-
Shop	0	0.6	1.9	4.1	-
Work	0	5.9	9.2	12.5	-

a. Happy



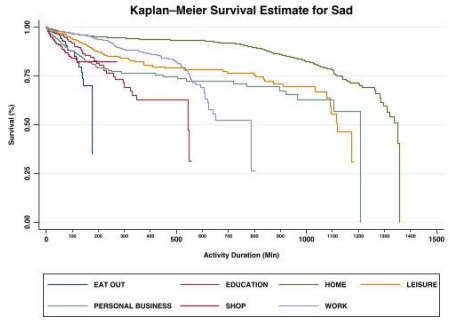
Activities	0%	25%	50%	75%	100%
Eating Out	0	1.9	2.9	-	-
Education	0	3.7	-	-	-
Home	0	12.4	17.2	21.4	22.5
Leisure	0	2.4	13.2	-	-
Personal Business	0	2.4	15.0	19.9	20
Shop	0	1.1	2.4	-	-
Work	0	5.4	9.1	12.6	-

b. Tired



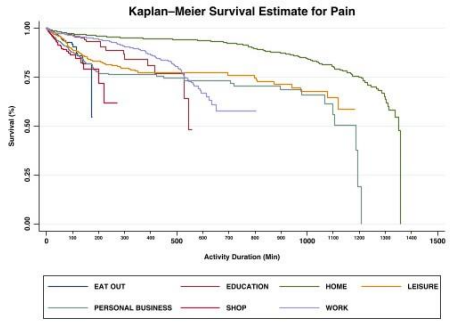
Activities	0%	25%	50%	75%	100%
Eating Out	0	1.9	2.9	-	-
Education	0	2.8	6.9	9.1	-
Home	0	14.4	19.9	22.5	22.7
Leisure	0	3.8	17.9	-	-
Personal Business	0	1.8	16.1	19.9	20.1
Shop	0	0.9	2.4	-	-
Work	0	4.7	8.6	10.1	-

c. Stress



Activities	0%	25%	50%	75%	100%
Eating Out	0	2.3	2.9	-	-
Education	0	4.3	9.0	-	-
Home	0	18.6	22.5	22.6	22.6
Leisure	0	13.4	18.6	-	-
Personal Business	0	7.4	20.1	20.1	20.1
Shop	0	-	-	-	-
Work	0	9.2	13.1	-	-

d. Sad



Activities	0%	25%	50%	75%	100%
Eating Out	0	2.9	-	-	-
Education	0	8.8	9.0	-	-
Home	0	20.1	22.5	22.6	22.6
Leisure	0	13.3	-	-	-
Personal Business	0	7.4	19.7	19.9	20.1
Shop	0	3.3	-	-	-
Work	0	8.8	-	-	-

e. Pain

443 **FIGURE 3** Survival probability of daily activity duration tolerance

We observe an increase in the percentage of participants who do not survive (whose emotions worsen) as the activity duration increases. In addition, we find that the percentage of individuals whose emotions worsen as the activity duration increases varies over different activities. Figure 3a represents the sample of the population that experience less happiness from engaging in activities. It is noticed that 75% of the population experience less happiness when shopping and working under approximately 4 hours and 12.5 hours, respectively. Except for eating out, half of the population experience worsening happiness, with home and personal business associated with the largest activity durations, whereas happiness worsens when shopping in under approximately 2 hours. For 25% of the population, all activities are subject to worsening happiness, with leisure associated with worsening happiness occurring in under 12.4 hours. Figure 3b represents the sample of the population that experiences more tiredness. We observe that 100% of the population experience more tiredness when conducting home and personal business activities, and 75% are more tired during home, personal business, and work activities, 25% and 50% percent of the population experience more tiredness for all activities with home and leisure with the longest DADT for 50% of the population. Home and work have the longest DADT for 25% of the population. For the sample population that feels more stressed per the depiction in Figure 3c, an increase in the activity duration results in 100% of participants feeling more stress in under 22.7 hours and 20.1 hours when engaging in home and personal business, respectively. This DADT is almost similar for 75% of participants for home and personal business activities. Other activities impacted by 75% of the population are education and work. Figure 3d represents the sample of the population that experiences more sadness from engaging in activities. It is inferred that 75% and 100% of the sample feel sadder for home and personal business, with similar DADT – 22.6 hours for home and 20.1 hours for personal business. Except for shopping, 25% and 50% of the population feel more sadness with home and personal business longest DADT. Figure 3e represents the sample of the population that experiences more pain from engaging in activities. As shown, 50%, 75%, and 100% of the sample population do not experience more pain from eating out, leisure, shopping, and work activities. Also, 25% of the sample population experienced worsening pain when engaging in all activities, with home and leisure associated with the most DADT.

Overall, we observe that negative emotions are tolerated for longer activity duration than the positive emotion of happiness. We tested whether it is due to participants experiencing less variability in negative emotions by measuring the standard deviation of each AWB in our sample. The standard

deviation equals 1.52, 1.66, 1.49, 1.09, and 1.26 for happy, tired, stress, sad, and pain. This does not fully support our hypothesis, albeit the variation in sad and pain is relatively low. We therefore speculate that participants are more familiar with the happiness emotion and are more comfortable to express it. When we go to a restaurant, for example, it is easier to express our experience with happiness. Rather than ascribing a value that participants can tolerate as a function of activity participation, Figure 3 shows the DADT differs for each AWB response in our sample as well as for the various activity types.

Commented [JDV1]: I think this sentence is what the reviewer is refering to as line 361. But I don't think the statements here are incorrect....

Correlates of DADT Acceleration

Characteristics accelerating DADT, regardless of the AWB, are travel mode to activities, and primary activities. Two observations are noticed. First, walking and biking affect the DADT of happiness and the tiredness. We did not find any statistically significant association between travel modes and the DADT of stress, sadness, and pain. Happiness worsens in a shorter activity duration for participants who walked or biked to activities. An explanation is our participants who biked or walked to an activity, on average, reported a higher happiness score at the beginning of their activity and consequently experienced a higher probability in worsening their happiness during the activity. More specifically, averaging over the sample, the starting happiness score of activities for bicyclists, pedestrians, transit users, and drivers equal 5.5, 5.1, 4.4, and 4.8, respectively. Although walking or biking is associated with a higher level of happiness, it diminishes the duration tolerance of its following activity. Second, all emotions worsen in a shorter activity duration performing out-of-home primary activities (i.e., work, leisure, eating out, education, personal business, shopping). The magnitude of effect is a function of the activity type and emotion, however. Happiness, stress, and sadness worsen in a shorter activity duration than tiredness and pain when conducting primary activities. Shopping or eating out is associated with the shortest activity duration depending on the emotion. Shopping worsens happiness, stress, and pain in a shorter activity duration than other primary activities and eating out worsens tiredness and sadness in a shorter activity duration than other primary activities.

We expanded our analysis by testing the interaction effects between primary activities and modes of travel to modify the effect of the two variables considered individually. The results indicate walking, biking, and taking transit has different impacts on the DADT of emotions depending on the primary activities. Happiness worsens in a shorter activity duration when participants walked or biked to leisure

activities, but it worsens in a longer activity duration when they used public transit to reach their personal business and shopping activities. Tiredness and stress worsen in a shorter activity duration when participants walked to work and leisure activities, and sadness worsens in a shorter activity duration when participants biked to work and leisure activities. However, stress and pain worsen in a longer activity duration when participants walked their personal business activities.

Another set of interaction effects between primary activities and companionship indicate performing activities with family, spouses, coworkers, and friends increases or decreases the activity duration tolerance depending on the activity type and companionship. The activity duration tolerance of happiness increases when working with friends or spouse, eating out with family and friends, having personal activities with family, and shopping with spouse. It, however, decreases when conducting leisure activities with colleagues and participating in education activities with spouse. The activity duration tolerance of tiredness increases when eating out with friends or spouse. It, however, decreases when working with friends and family, conducting leisure activities with friends, participating in education activities with spouse, and shopping with family or friends. The activity duration tolerance of stress increases when eating out with family or friends, conducting personal business with family or friends, and shopping with spouse. It, however, decreases when participating in education activities with spouse. The activity duration tolerance of sadness decreases when eating out with colleagues and shopping with family. The activity duration tolerance of pain also decreases when conducting leisure activities with spouse.

Physical activity, initial AWB, and ethnicity have both acceleration and deceleration effect depending on the AWB. Not surprisingly, pain worsens in a shorter travel time if the activity involves moderate or vigorous physical activity. However, happiness worsens in a longer travel time. An activity involving physical is associated with a shorter DADT of pain, but a longer DADT of happiness. We also noticed that the AWB score of travelers at the beginning of the activity accelerates the DADT of positive emotion of happiness and decelerates the DADT of negative emotions. Happiness worsens in a shorter travel time if participants begin their activity with a higher happiness score, while negative emotions worsen in a longer travel time if participants begin their activity with a higher tired, stress, sad, and pain score. African American is the sole ethnicity characteristic decelerating the DADT of happiness and accelerating the DADT of tiredness, sadness, and pain. It means African Americans participated in our study experienced a longer activity duration before their happiness worsens, while experienced a shorter travel duration before their tiredness, sadness, and pain worsen.

538

539 **Correlates of DADT Deceleration**

540 Characteristics decelerating DADT are activity companionship, secondary activities, time of the day,
541 and satisfaction with the environment Happiness happens to be more sensitive to activity
542 companionship, secondary activities, time of the day, and satisfaction with the environment by
543 displaying more statistically significant variables and higher deceleration factors. Pain is less sensitive,
544 however. Four concrete observations are decerned. First, conducting activities with family, spouses,
545 coworkers, and friends is associated with tolerating longer activity durations. Activity duration
546 tolerance of happiness and tiredness is greatest when travelers are accompanied by coworkers and
547 friends. Activity duration tolerance of stress, sadness, and pain is greatest when travelers are
548 accompanied by spouse.

549 Second, secondary activities involving religion, caring, and gardening are associated with tolerating
550 longer activity durations. Happiness and stress worsen in longer activity duration when engaging in
551 religious activities, happiness, tiredness, and pain worsen in longer activity duration when activities
552 involve caring, and happiness, tiredness, and stress worsen in longer activity duration when activities
553 involve gardening. Sadness has found to be the solely emotion not affected by secondary activities in
554 our sample. Third, regardless of the AWB emotions, activities conducted in evening and midnight are
555 associated with tolerating longer activity durations. Fourth, if the traveler is satisfied by the
556 environment of the activity all AWB responses worsen in longer activity duration with the DADT of
557 happiness is the longest and the DADT of tiredness is the shortest. The interaction effects between
558 primary activities and environment satisfaction reveals the DADT is more sensitive to environment
559 satisfaction when conducting specific activities. The DADT of happiness and stress increases when
560 participants were satisfied with the environment of their leisure activities and the DADT of tiredness
561 increases when participants were satisfied with the environment of their work and eat out.

562

563 **CONCLUSION**

564 We introduced the concept of daily activity duration tolerance and explored how it affects individuals'
565 affective well-being (i.e., happiness, tiredness, stress, sadness, pain). "Daily Activity Duration
566 Tolerance" (DADT) is, in essence, the duration whereby affective well-being responses worsen as a
567 function of activity- and individual-level characteristics. The analysis in this paper was conducted using

the Daynamica smartphone application, whereby participants self-reported their positive and negative affective well-being responses, including happiness, tiredness, stress, sadness, and pain in response to various trip and activity episodes. Hazard-based duration modeling was employed on the data set for each affective well-being response.

We found that negative affects are tolerated for longer activity duration than the positive affect of happiness, and 100% of the sample population feel more negative emotions when conducting home and personal business activities. We also explored how the mode of travel to activities, primary activities, and physical activities affect the acceleration of DADT. Biking to activities results in the tolerance of shorter activity durations before happiness levels drop. Similar outcomes were found for walking. These outcomes partly contradict existing travel satisfaction studies, indicating that active travel is the most satisfying mode of travel. We speculate this difference is because we examined the impact of the mode of travel on the activity rather than examining how travel mode is associated with travel satisfaction. Regardless of positive and negative emotions, we found that activity duration tolerance is shorter for primary activities of shopping, personal business, and eating out than education, work, and leisure. Engagement in daily activities is inevitable and constitutes the bulk of an individual's life. On a maximum and over a seven consecutive day period, participants in this study reported extensive time on out-of-home primary activities: 40 hours for personal business, 32 hours working, 32 hours on leisure, 12 hours on education, 10 hours eating out, and 9 hours shopping. Hence, the add-on wear and tear on the individual's state of well-being is bound to ensue from the extended activity durations. Past studies delineated the affective responses to mandatory and discretionary activities, and the findings suggested higher favorability and increased levels of positive affect when engaging in discretionary activities (Archer et al., 2013; Pendyala et al., 2018; Raveau et al., 2016). Our findings also implied that activity duration tolerance becomes longer when activities are conducted with companionship, particularly with co-workers and friends. These results are synchronous with past research that revealed that the affective state depends on the companion (Glasgow et al., 2018; Lancée et al., 2017; Páez and Whalen, 2010; Zhu and Fan, 2018). Additionally, we discovered that secondary activities such as religion, caring, and gardening lead to tolerating longer activity durations, just as activities conducted during the evening or at midnight. Finally, we showed that the chance of happiness worsening is lower for African Americans with similar activity durations than individuals of other ethnic backgrounds, and they tolerate longer activity duration before their happiness worsens.

In sum, this study showed that the rate of deceleration of various affective emotions differs. This reduction in emotional experience is mainly affected by the mode used to reach activities, the type of activity, and the companionship when performing activities. This is the first study that analyzed to what extent and how the experience of emotions during activities diminishes in time. With regards to specific transport policy initiatives, it is important to reduce the diminishing rate of positive emotions (e.g., happiness) and increase the diminishing rate of negative emotions (e.g., stress) since the experience of emotions has a strong impact on subjective well-being and quality of life (Lyubomirsky et al., 2005). For travel mode to activities, it is possible that the physical and intense nature affiliated with cycling and walking is linked to tolerating shorter commute duration and negative emotions (He et al., 2016; Milakis et al., 2015; Raveau et al., 2016; Zhu and Fan, 2018). Little was known about how and to what extent travel mode to an activity impacts the tolerable duration of that activity. Our results echo previous research emphasizing the need for suitable design and destination access that offer the added benefits of improved personal health, less reliance on auto vehicles, and a sustainable environment. Adequate infrastructure and connectivity (i.e., neighborhood, trail, path, pedestrian street, sidewalks) are directly linked to the ability of individuals to feel safe and comfortable within the urban environment, increasing the level of interest in active travel, and improving the experience of active trips, therefore, reduce the deceleration of positive emotions. This is evidenced by the findings on the association between travel and built environment features (Ye and Titheridge, 2017). For the type of activity, planning strategies should create avenues for diversity of discretionary activities (e.g., eating out, leisure, shopping, personal business) that alleviate negative responses. Moreso, individuals have a strong desire to easily access these destinations, provisions for supporting infrastructure, and within reasonable distances. For instance, shorter commute times (living closer to jobs or improving transport access) may result in more time spent on more rewarding activities.

Although this study is insightful into activity- and individual-level influences that deteriorate positive and negative affect, we recognize limitations that create areas for future research. First, the sample size is slightly biased and does not represent the Minneapolis-St. Paul Metropolitan Area. This is largely attributed to the initial introduction of smartphone technologies for data collection. Though efforts were made to recruit as many households as possible from random blocks representing the six study neighborhoods, the recruitment still proved challenging due to skepticism of revealing private information and the willingness to participate for seven consecutive days. We, therefore, avoided emphasizing the role of age and gender in our analysis. Second, the survey questionnaire lacks inquiries

on participant attitudes and preferences toward activities. Although active travel modes were observed to diminish affective well-being in a short duration, further inquiry on the preferred travel mode might reveal a preference towards active travel modes, which could be attributed to the built environment features. Third, the study area is limited to six neighborhoods unique to the Minneapolis-St. Paul Metropolitan Area. Adoption of these study results should factor in geographical contexts. While the translation of the study and policy implications are valid, practitioners should consider the differences in built environment features, development, lifestyle, and other areas that necessitate assessment before implementation. Fourth, our study is limited to out-of-home activities as (i) the nature of out-of-home activities is different from in-home activities and it requires a completely different discussion and (ii) our data does not support activities conducted at home. Our methodology, however, can be simply adopted to analyze in-home activities should the data is available for in-home activities.

STATEMENTS AND DECLARATIONS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

The datasets used or analyzed during the current study will be available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: A. Ermagun; analysis and interpretation of results: A. Ermagun, J. Erinne; draft manuscript preparation: A. Ermagun, J. Erinne, and J. De Vos. All authors reviewed the results and approved the final version of the manuscript.

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Appendix

Table A1 Coefficient Estimates of Proportional Hazards Models

Variables	Coefficients (t-test)				
	Model 1 Happy	Model 2 Tired	Model 3 Stress	Model 4 Sad	Model 5 Pain
Activity-Level Characteristics					
WORK	.860 (7.45)	.695 (3.49)	1.110 (7.28)	.761 (4.94)	.322 (2.59)
EDUCATION	1.188 (7.66)	.424 (1.98)	.774 (2.78)	1.591 (3.40)	.602 (2.39)
LEISURE	1.044 (5.62)	.450 (3.83)	1.346 (7.19)	1.191 (8.14)	1.075 (5.98)
EATING	2.478 (4.76)	1.716 (5.34)	1.833 (7.60)	1.693 (9.17)	.801 (2.43)
PERSONAL	2.252 (7.90)	1.123 (12.41)	1.836 (17.33)	1.600 (11.95)	1.385 (10.25)
SHOP	2.914 (10.16)	1.249 (7.32)	2.096 (19.27)	1.597 (7.07)	1.629 (10.16)
WALK	.173 (2.53)	-.144 (-1.86)			
BIKE	.194 (1.86)				
PHYSICAL	-.269 (-4.03)				.501 (5.11)
SPOUSE	-.523 (-6.68)	-.275 (-4.09)	-.524 (-7.06)	-.475 (-4.42)	-.264 (-2.13)
FAMILY	-.375 (-3.68)	-.371 (-4.32)			
WORKPEOP	-.780 (-6.91)	-.426 (-3.81)	-.274 (-2.62)	-.645 (-3.95)	
FRIENDS	-.748 (-8.38)	-.420 (-4.33)	-.135 (-1.70)	-.218 (-2.15)	
RELIGION	-.896 (-4.32)		-.279 (-1.79)		
CARING	-.251 (-3.20)	-.146 (-2.14)			-.419 (-3.48)
GARDENING	-.376 (-2.64)	-.332 (-2.83)	-.518 (-3.61)		
EVENING	-.371 (-6.26)	-.091 (-1.70)	-.353 (-5.88)	-.192 (-2.26)	-.218 (-2.47)
MIDNIGHT	-.510 (-4.19)	-.144 (-1.80)	-.632 (-5.01)	-.479 (-2.73)	-.458 (-2.50)
ENVIRONMENT SATISFACTION	-.835 (-13.25)	-.133 (-1.78)	-.467 (-7.01)	-.433 (-4.59)	-.310 (-3.17)
WORK_WALK		.407 (2.54)	.209 (1.63)		
LEISURE_WALK	.491 (2.81)	.557 (3.55)	.530 (3.23)		
EDUCATION_WALK		.918 (2.97)			
PERSONAL_WALK			-.509 (-2.37)		-.547 (-1.83)
WORK_BIKE				.591 (1.71)	
LEISURE_BIKE	1.079 (4.07)			.825 (1.95)	
PERSONAL_TRANSIT	-.539 (-1.80)				
SHOP_TRANSIT	-.874 (-2.10)				
WORK_FRIENDS	.546 (2.48)	.473 (2.44)			
WORK_FAMILY		1.001 (3.46)			
WORK_SPOUSE	.479 (1.66)				
LEISURE_FRIENDS		.506 (3.34)			
LEISURE_SPOUSE					-0.677 (-2.51)
LEISURE_WORKPEOP	1.354 (2.54)				
EDUCATION_SPOUSE	1.009 (2.52)	1.001 (2.29)	.776 (1.85)		
EATING OUT _FAMILY	-.747 (-2.14)		-.654 (-2.08)		
EATING OUT_FRIENDS	-.626 (-2.21)	-.689 (-2.39)	-1.001 (-3.62)		
EATING OUT_SPOUSE		-.498 (-1.73)			
EATING OUT_WORKPEOP				1.526 (2.70)	
PERSONAL_WORKPEOP					
PERSONAL_FAMILY	-.387 (-1.71)		-.448 (-2.25)		
PERSONAL_FRIENDS			-.448 (-2.39)		
SHOP_FAMILY		.595 (2.59)		.541 (1.79)	
SHOP_SPOUSE	.323 (1.89)		.451 (2.28)		
SHOP_FRIENDS		.540 (2.04)			
LEISURE_ PHYSICAL		.672 (5.74)		-.398 (-1.92)	.509 (2.47)
PERSONAL_PHYSACAL				-.695 (-2.43)	
LEISURE_ SATISFY	-.677 (-3.63)		-.624 (-3.23)		
WORK_SATISFY		-.295 (-2.03)			
EATING OUT _SATISFY		-.503 (-1.87)			

EDUCATION_SATISFY			.625 (2.05)	.808 (2.00)	
INITIAL AWB	.654 (21.53)	-.358 (-16.24)	-.349 (-12.98)	-.288 (-6.03)	-.271 (-6.70)
WORK INITIAL AWB		-.090 (-1.95)	-.139 (-2.77)		
EATING INITIAL AWB	-.152 (-1.83)	.160 (1.99)	.162 (1.83)		.226 (1.89)
EDUCATION INITIAL AWB				-.539 (-2.20)	
PERSONAL INITIAL AWB	.083 (-1.83)				
SHOP INITIAL AWB	-.138 (-2.71)	.165 (3.13)		.162 (1.92)	
Individual-Level Characteristics					
AGE	-.017 (-5.20)	-.021 (-7.30)	-.022 (-6.86)	-.019 (-4.01)	-.009 (-1.67)
BLACK	-.570 (-3.01)	.260 (1.73)	-	.640 (2.50)	.903 (3.04)
Constant	-8.121 (-31.65)	-5.354 (-25.83)	-5.359 (-24.16)	-6.700 (-21.63)	-7.44 (-21.38)
Number of Observations	9,618	9,615	9,618	9,611	9,607
Number of Groups	353	353	353	351	351
Ln (p)	-0.173	0.053	0.016	-0.034	-0.059
p	0.841	1.055	1.016	0.965	0.942

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