

## TRANSPORT FINDINGS

# Evaluating Rules for Aggregating Satisfaction with Activity-travel Episodes to a Day-level Satisfaction Measure

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## Findings

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The recent interest in developing subjective wellbeing aggregation rules in transport research has triggered dialogue across disciplines. Here we analyze how 10 different aggregation rules result in different day-level indicators of satisfaction based on separate measures for each activity and trip on the day and compare the resulting distribution of day-level scores with those for life satisfaction. We find that the normative rules outperform the heuristic rules and are best used to create day-level indicators of satisfaction with activities and trips if the aim is to mimic the statistical distribution for life satisfaction scores.

## 1. Questions

Several studies have explored aggregation rules for subjective wellbeing (SWB) based on daily travel-activity episodes (Suzuki et al. 2014; Abenoza, Cats, and Susilo 2018; Gao et al. 2018), which can be classified as heuristic or normative ([Table 1](#)). According to heuristic rules, people consider all activity-travel episode in creating an overall evaluation, while normative rules assume that people consider one or two episodes exclusively in composing an overall evaluation. Earlier studies were separately conducted in the three largest urban areas of Sweden, eight European cities, and Xi'an City, China, and they indicate that normative rules outperform heuristic ones. However, findings have not been evaluated in other geographical contexts using different datasets. Additionally, the aggregation rules have not been examined in relation to life satisfaction (the evaluation of one's life as a whole) (Diener et al. 1999), the most widely used measurement of SWB, as the relationship between short-term and long-term SWB has become an area of major research interest in interdisciplinary wellbeing research (Kansky and Diener 2021).

The research question is whether and to what extent the episode-based aggregated day-level satisfaction is related to life satisfaction. We address the question by addressing (1) to what extent do different rules for aggregating satisfaction with individual activity and trip episodes during a day (24h) generate different day-level measures of satisfaction?; and (2) which rule generates a day-level indicator that is most strongly closely correlated with a conventional life satisfaction measure? Data from a recent travel-activity diary survey with rich information in a suburban residential community in Beijing is used for the analysis.

## 2. Methods

117 residents from the Meiheyuan residential community in Beijing's inner suburbs were recruited using stratified clustered random sampling based on housing types (commodity housing, *danwei* housing, and public low-rent housing) between November 2017 and January 2018 to gather information on activity-trip episodes and SWB during those episodes on one weekday and one weekend day, and on life satisfaction and socio-economic status. 225 out of  $2 \times 117 = 234$  person-days were valid after deleting the person-days lacking information on full activity-travel episodes. The sample is diverse in terms of sociodemographic profile, but there is an over-representation of older adults, those with a college degree and those with Beijing local *hukou* (a household registration system associated with local welfare) compared to the wider Meiheyuan residential community and the Qinghe District in which it is located.

To calculate the day-level satisfaction from satisfaction with activity episodes and trips, we modified the 10 aggregation rules from Miron-Shatz (2009), Suzuki et al. (2014), Abenoza et al. (2018) and Gao et al. (2018) as summarized in [Table 1](#). The performance of the rules is assessed in terms of the statistical association of the constructed day-level indicator of satisfaction with a conventional life satisfaction indicator, which consists of the five-category response (from very dissatisfied to very satisfied) to the survey question of 'in general, how much you are satisfied with your life?'. We use the latter indicator as a yardstick because it is the key part and the most widely used measure of SWB (Diener et al. 1999). The association between episode-based aggregated day-level satisfaction and life satisfaction is examined using descriptive analysis and OLS regression. Though the systematic differences in those relationships according to day of the week sociodemographic variables have been tested, the results provided few new insights and are therefore not presented.

We created two statistical indices to examine the distributions of episode-based aggregated day-level satisfaction in relation to that of life satisfaction for the ten rules. Index (1) considers the aggregated absolute difference between day-level satisfaction and life satisfaction for each person-day, and Index (2) the same difference after the distributions for day-level satisfaction and life satisfaction have been centred on their respective means:

$$I_{1i} = \sum_{ni} |DS_{ni} - LS_m| \quad (1)$$

$$I_{2i} = \sum_{ni} \left| |DS_{ni} - \overline{DS_{ni}}| - |LS_m - \overline{LS_m}| \right| \quad (2)$$

Table 1. Ten aggregation rules of SWB

| Aggregation rules |                                       | Description                                                            | Formula                                                                                                 | Theoretical foundation                                      |
|-------------------|---------------------------------------|------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|
| Normative rules   | EWA: Equal-weighted averaging rule    | Mean value of all episodes                                             | $\frac{\sum_{i=1}^I S_{ni}}{I_n}$                                                                       | Anderson (1981) Information integration theory              |
|                   | DWA: Duration-weighted averaging rule | Weighted average value based on the duration of each episode           | $\frac{\sum_{i=1}^I \Delta_{ni} S_{ni}}{\sum_{i=1}^I \Delta_{ni}}$                                      | Anderson (1981) Information integration theory              |
| Heuristic rules   | End rule                              | Value of the end episode                                               | $S_{nI}$                                                                                                | Diener, Wirtz, and Oishi (2001) James Dean effect           |
|                   | Serial position rule                  | Mean value of the start and the end episodes                           | $(S_{n1} + S_{nI})/2$                                                                                   | de Bruin (2005) Serial position effect                      |
|                   | Peak rule                             | Value of the episode with the largest deviation from the mean          | $\max_{ni} \left  S_{ni} - \frac{\sum_{i=1}^I S_{ni}}{I_n} \right $                                     | Rasouli and Timmermans (2015) Bounded rationality           |
|                   | Peak(high) rule                       | Value of the episode with the largest positive deviation from the mean | $\max_{ni} \left( S_{ni} - \frac{\sum_{i=1}^I S_{ni}}{I_n} \right)$                                     | Rasouli and Timmermans (2015) Bounded rationality           |
|                   | Peak(low) rule                        | Value of the episode with the largest negative deviation from the mean | $\min_{ni} \left( S_{ni} - \frac{\sum_{i=1}^I S_{ni}}{I_n} \right)$                                     | Rasouli and Timmermans (2015) Bounded rationality           |
|                   | Peak-end rule                         | Mean value of the peak and the end episodes                            | $\frac{\left( S \max_{ni} \left  S_{ni} - \frac{\sum_{i=1}^I S_{ni}}{I_n} \right  + S_{nI} \right)}{2}$ | Kahneman (2000) Hedonic adaptation/hedonic treadmill effect |
|                   | Peak(high)-end rule                   | Mean value of the peak high episode and the end episode                | $\frac{\left[ S \max_{ni} \left( S_{ni} - \frac{\sum_{i=1}^I S_{ni}}{I_n} \right) + S_{nI} \right]}{2}$ | Kahneman (2000) Hedonic adaptation/hedonic treadmill effect |
|                   | Peak(low)-end rule                    | Mean value of the peak low episode and the end episode                 | $\frac{\left[ S \min_{ni} \left( S_{ni} - \frac{\sum_{i=1}^I S_{ni}}{I_n} \right) + S_{nI} \right]}{2}$ | Kahneman (2000) Hedonic adaptation/hedonic treadmill effect |

Note: Let  $i_n = \{i_n \in I_n\}$ ;  $I_n > 0$  be the chronologically ordered daily travel-activity episodes individual  $n$  makes on a given day.  $S_{ni}$  is the satisfaction of episode  $i$  for individual  $n$ .  $\Delta_{ni}$  is the duration of episode  $i$  for individual  $n$ .  $S_{n1}$  and  $S_{nI}$  denote  $n$ 's satisfaction with the first and last episode on the day, respectively.

where  $DS_{ni}$  and  $LS_m$  denote the day-level satisfaction calculated for person-day  $n$  (1,2,3...N) using aggregation rule  $i$  (1,2,3...10) and the life satisfaction for person  $m$  (1,2,3...M), respectively. Index (1) considers differences in both the mean and the shape of the distribution between the aggregation rule scores and life satisfaction, while Index (2) only compares the shape of distribution because the difference in the mean has been taken out.

### 3. Findings

[Table 2](#) summarizes the distribution of the day-level satisfaction measures and how these are related to that of life satisfaction. The mean values for the peak, peak-low, peak-end and peak(low)-end rules are close to the average level of life satisfaction. Index (1) shows that peak(low)-end and peak-low rules

have the lowest absolute difference with life satisfaction for each person-day, followed by the EWA and DWA rules. These rules thus create distributions where not only the shape but also the mean values are closest to that for life satisfaction. However, Index (2) indicates that the peak(high), peak(high)-end, EWA and DWA rules are the most closely related to life satisfaction when the centred distributions are used, suggesting that the shape of their distributions are the most similar to that for life satisfaction.

[Table 3](#) shows the OLS regression results of day-level satisfaction on life satisfaction (LS) by aggregation rule. The normative rules (EWA and DWA) are associated most strongly with study participants' life satisfaction with  $R^2$  values of 0.173 and 0.165, respectively, followed by peak(low)-end and peak(high)-end rules among the heuristic rules. The models for the normative rules (EWA and DWA) not only have larger  $R^2$  values but also larger standardised regression coefficients and smaller constants compared with those for the heuristic rules.

The peak(low)-end rule and peak(high)-end rule clearly outperform the peak-end rule, meaning that unidimensional retrospective valuation of daily experience at either highs or lows explains life satisfaction better than the valuation considering both sides.

The findings show that individuals' day experience is more likely to be a process shaped by all the activity-travel episodes rather than one or two episodes with the peak emotions or at the end. Thus, we recommend the use of normative rules for day-level satisfaction measures that are based on the aggregation of episode-based scores, because this will generate value distributions that map closely onto the distribution of life satisfaction. Within the set of heuristic rules, the peak-end rule is more closely related to life satisfaction when the high or low peaks are considered separately.

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Table 2. Descriptive statistics of the 10 aggregation rules and life satisfaction (N=225)

|                | EWA    | DWA    | END    | Serial position | Peak   | Peak(high) | Peak(low) | Peak-end | Peak(high)-end | Peak(low)-end | Life satisfaction |
|----------------|--------|--------|--------|-----------------|--------|------------|-----------|----------|----------------|---------------|-------------------|
| Mean           | 4.051  | 4.099  | 4.173  | 4.171           | 3.667  | 4.560      | 3.289     | 3.918    | 4.364          | 3.729         | 3.427             |
| Std. Deviation | 0.636  | 0.652  | 0.830  | 0.781           | 1.138  | 0.596      | 0.969     | 0.815    | 0.646          | 0.783         | 0.848             |
| Skewness       | -0.092 | -0.250 | -1.044 | -0.987          | -0.381 | -1.002     | -0.043    | -0.750   | -0.808         | -0.466        | -0.544            |
| Kurtosis       | -0.795 | -0.615 | 1.338  | 1.392           | -0.872 | 0.008      | -0.416    | 0.560    | -0.054         | 0.484         | 0.475             |
| Index (1)      | 185.0  | 194.1  | 224.0  | 219.5           | 230.0  | 269.0      | 181.0     | 201.5    | 237.0          | 177.0         | --                |
| Index (2)      | 149.4  | 152.1  | 174.4  | 165.6           | 235.5  | 146.5      | 190.7     | 174.7    | 148.7          | 169.5         | --                |

Table 3. OLS regression models (N=225)

| Dependent variable: LS           | EWA   | DWA   | END   | Serial position | Peak  | Peak(high) | Peak(low) | Peak-end | Peak(high)-end | Peak(low)-end |
|----------------------------------|-------|-------|-------|-----------------|-------|------------|-----------|----------|----------------|---------------|
| Constant                         | 1.178 | 1.263 | 2.091 | 1.868           | 2.934 | 1.346      | 2.562     | 2.257    | 1.421          | 2.002         |
| Standardized coefficient $\beta$ | .416  | .406  | .313  | .344            | .180  | .320       | .300      | .287     | .350           | .353          |
| t-statistic                      | 6.838 | 6.631 | 4.925 | 5.476           | 2.740 | 5.051      | 4.703     | 4.471    | 5.585          | 5.635         |
| Sig.                             | .000  | .000  | .000  | .000            | .007  | .000       | .000      | .000     | .000           | .000          |
| $R^2$                            | .173  | .165  | .098  | .119            | .033  | .103       | .090      | .082     | .123           | .125          |