Supplementary materials for **“Porosity, openness, and exposure: Identification of underlying factors associated with semi-outdoor spaces’ microclimate performance and clustering in tropical high-density Singapore”**

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**Figure S 1*.*** Interactive 3D scatter plot showing factor scores for each of the underlying factors retained by EFA (i.e. VP, PO, ES) and clusters (i.e. *vertical breezeways, horizontal breezeways, perimeter buffers*) to which they belong. *Note: Double-click the icon to be redirected to an HTML document that will open in your default browser.*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Building (period) | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7 | Day 8 | **Mean** |
| SO (June 10 - 17, 2019) | 30.90 | 32.42 | 28.27\*\* | 29.94 | 30.66 | 30.38 | 30.80 | 30.90 | 30.86 |
| OA (June 26 - July 02, 2019) | 28.21 | 31.18 | 31.49 | 30.05\*\* | 29.42 | 31.46 | 31.55 | NA | 30.55 |
| KA (July 09 - 16, 2019) | 28.59\*\* | 32.83 | 32.99 | 32.41\*\* | 34.12 | 34.12 | 27.91 | 30.15\*\* | 32.40 |
| SV (July 24 - 30, 2019) | 29.16\*\* | 30.45 | 30.57 | 30.90 | 30.39 | 31.03 | 30.80 | NA | 30.69 |

**Table S1.** Outdoor air temperature at 2 p.m. (ºC) in each building for each measured day. Note: Blank values (\*\*) correspond to rainy days, not included in the analysis, and NA corresponds to days not measured.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Building (number of SOS) | Tout | Ta | ΔT | p-value (*p*) |
| SO (n = 12) | 30.86ºC | 29.85ºC | 1.01ºC | *p* <.001 |
| OA (n = 16) | 30.55ºC | 29.20ºC | 1.35ºC | *p* <.001 |
| KA (n = 4) | 32.40ºC | 30.00ºC | 2.41ºC | *p* =.011 |
| SV (n = 31) | 30.69ºC | 29.88ºC | 0.79ºC | *p* <.001 |

**Table S2.** Comparison per building between mean Ta in semi-outdoor spaces and the mean Tout. Note: p-value (p) is from Mann-Whitney’s test for one sample. Full analysis explained in <https://doi.org/10.1016/j.enbuild.2020.110544>

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Mean | Min. | Max. | Std. | Kurt. | Skew. | CV |
| Ta (ºC) | 29.71 | 28.45 | 31.95 | 0.60 | 2.03 | 0.68 | 2.01% |
| Tmrt (ºC) | 32.40 | 28.15 | 36.62 | 1.78 | -0.19 | 0.11 | 5.49% |
| Va (m/s) | 0.87 | 0.17 | 2.10 | 0.56 | -0.16 | 1.00 | 64.37% |
| RH (%) | 70.10 | 57.80 | 79.17 | 5.53 | -1.33 | 0.00 | 7.89% |
| SET\* 1 MET (ºC) | 26.43 | 24.65 | 29.73 | 1.11 | 0.13 | 0.53 | 4.20% |
| SET\* 1.5 MET (ºC) | 28.05 | 25.57 | 30.61 | 1.34 | -0.92 | -0.19 | 4.78% |
| SET\* 2 MET (ºC) | 29.51 | 26.67 | 32.01 | 1.42 | -0.82 | -0.53 | 4.82% |
| PMV\* 1 MET | 0.63 | -0.10 | 1.80 | 0.42 | -0.11 | 0.20 | 66.67% |
| PMV\* 1.5 MET | 0.94 | 0.21 | 1.67 | 0.38 | -0.86 | -0.33 | 40.43% |
| PMV\* 2 MET | 1.26 | 0.49 | 1.92 | 0.38 | -0.75 | -0.57 | 30.16% |
| PET\* 1 MET (ºC) | 29.81 | 28.18 | 31.59 | 0.84 | -0.66 | 0.02 | 2.82% |
| PET\* 1.5 MET (ºC) | 30.61 | 28.76 | 32.74 | 0.96 | -0.61 | -0.02 | 3.14% |
| PET\* 2 MET (ºC) | 31.41 | 29.33 | 33.87 | 1.08 | -0.59 | -0.05 | 3.44% |

**Table S3.** Descriptive statistics (mean, minimum, maximum, standard deviation, kurtosis, skewness and coefficient of variation of microclimate variables and predicted thermal comfort.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Ta | Tmrt | Va | RH |
| Ta | 1\* |  |  |  |
| Tmrt | -0.23 | 1\* |  |  |
| Va | 0.08 | 0.53\* | 1\* |  |
| RH | -0.41\* | -0.49\* | -0.31\* | 1\* |

**Table S4.** Pearson’s correlation coefficients of microclimate variables. *Note: \* indicates p-values < 0.05*



**Figure S 2*.*** Scatterplot showing association of Ta, Tmrt, and Tout with RH at 2 p.m.

Chart, histogram

Description automatically generated

**Figure S 3*.*** Histograms depicting variations in microclimate variables in semi-outdoor spaces at 2 p.m.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Ta ~ VP + PO + ES**  (R2 = 0.096, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 29.70857 | 0.07408 | - | 401.044 | *p* <.001 | 1.000 |
| VP | 0.13543 | 0.08523 | 0.22483080 | 1.589 | *p* =.117 | 1.308 |
| PO | 0.12458 | 0.08352 | 0.20690319 | 1.492 | *p* =.141 | 1.394 |
| ES | 0.01300 | 0.09400 | 0.02163158 | 0.138 | *p* =.891 | 2.043 |

**Table S5.** Multivariate regression measuring the association of underlying factors with Ta.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tmrt ~ VP + PO + ES**  (R2 = 0.231, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 32.4000 | 0.2012 | - | 161.050 | *p* <.001 | 1.000 |
| VP | 0.9100 | 0.2315 | 0.5131347 | 3.931 | *p* <.001 | 1.308 |
| PO | -0.2395 | 0.2268 | -0.1351211 | -1.056 | *p* =.295 | 1.394 |
| ES | 0.3133 | 0.2553 | 0.1771440 | 1.227 | *p* =.225 | 2.043 |

**Table S6.** Multivariate regression measuring the association of underlying factors with Tmrt.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Va ~ VP + PO + ES**  (R2 = 0.351, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 0.86962 | 0.05481 | - | 15.866 | *p* <.001 | 1.000 |
| VP | 0.22196 | 0.06306 | 0.4221209 | 3.520 | *p* <.001 | 1.308 |
| PO | -0.21665 | 0.06179 | -0.4122082 | -3.506 | *p* <.001 | 1.394 |
| ES | -0.10141 | 0.06955 | -0.1933514 | -1.458 | *p* =.150 | 2.043 |

**Table S7.** Multivariate regression measuring the association of underlying factors with Va.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **RH ~ VP + PO + ES**  (R2 = 0.273, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 70.1027 | 0.6091 | - | 115.087 | *p* <.001 | 1.000 |
| VP | -3.0006 | 0.7009 | -0.5433986 | -4.281 | *p* <.001 | 1.308 |
| PO | 0.6635 | 0.6868 | 0.1202209 | 0.966 | *p* =.338 | 1.394 |
| ES | -1.9272 | 0.7730 | -0.3499050 | -2.493 | *p* <.001 | 2.043 |

**Table S8.** Multivariate regression measuring the association of underlying factors with RH.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SET\* (1 MET) ~ VP + PO + ES**  (R2 = 0.197, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 26.43101 | 0.12840 | - | 205.844 | *p* <.001 | 1.000 |
| VP | -0.26236 | 0.14774 | -0.23687714 | -1.776 | *p* =.081 | 1.308 |
| PO | 0.45456 | 0.14477 | 0.41059388 | 3.140 | *p* <.001 | 1.394 |
| ES | 0.09793 | 0.16294 | 0.08864094 | 0.601 | *p* =.550 | 2.043 |

**Table S9.** Multivariate regression measuring the association of underlying factors with SET\* (1 MET).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SET\* (1.5 MET) ~ VP + PO + ES**  (R2 = 0.300, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 28.0541 | 0.1444 | - | 194.216 | *p* <.001 | 1.000 |
| VP | -0.4876 | 0.1662 | -0.36542327 | -2.934 | *p* <.001 | 1.308 |
| PO | 0.5989 | 0.1629 | 0.44899787 | 3.677 | *p* <.001 | 1.394 |
| ES | 0.1249 | 0.1833 | 0.09380398 | 0.681 | *p* =.498 | 2.043 |

**Table S10.** Multivariate regression measuring the association of underlying factors with SET\* (1.5 MET).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SET\* (2 MET) ~ VP + PO + ES**  (R2 = 0.352, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 29.5058 | 0.1482 | - | 199.144 | *p* <.001 | 1.000 |
| VP | -0.5383 | 0.1705 | -0.3785066 | -3.158 | *p* <.001 | 1.308 |
| PO | 0.6960 | 0.1670 | 0.4896410 | 4.167 | *p* <.001 | 1.394 |
| ES | 0.2213 | 0.1880 | 0.1560254 | 1.177 | *p* =.244 | 2.043 |

**Table S11.** Multivariate regression measuring the association of underlying factors with SET\* (2 MET).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **PMV\* (1 MET) ~ VP + PO + ES**  (R2 = 0.296, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 0.633101 | 0.045156 | - | 14.020 | *p* <.001 | 1.000 |
| VP | -0.166154 | 0.051956 | -0.399437667 | -3.198 | *p* <.001 | 1.308 |
| PO | 0.174785 | 0.050911 | 0.420384343 | 3.433 | *p* <.001 | 1.394 |
| ES | 0.002315 | 0.057302 | 0.005578421 | 0.040 | *p* =.967 | 2.043 |

**Table S12.** Multivariate regression measuring the association of underlying factors with PMV\* (1 MET).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **PMV\* (1.5 MET) ~ VP + PO + ES**  (R2 = 0.350, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 0.93899 | 0.03973 | - | 23.637 | *p* <.001 | 1.000 |
| VP | -0.17202 | 0.04571 | -0.45164083 | -3.764 | *p* <.001 | 1.308 |
| PO | 0.16659 | 0.04479 | 0.43759013 | 3.720 | *p* <.001 | 1.394 |
| ES | 0.01135 | 0.05041 | 0.02988362 | 0.225 | *p* =.823 | 2.043 |

**Table S13.** Multivariate regression measuring the association of underlying factors with PMV\* (1.5 MET).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **PMV\* (2 MET) ~ VP + PO + ES**  (R2 = 0.376, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 1.25895 | 0.03849 | - | 32.707 | *p* <.001 | 1.000 |
| VP | -0.16551 | 0.04429 | -0.4394657 | -3.737 | *p* <.001 | 1.308 |
| PO | 0.17794 | 0.04340 | 0.4726860 | 4.100 | *p* <.001 | 1.394 |
| ES | 0.03613 | 0.04885 | 0.0961892 | 0.740 | *p* =.462 | 2.043 |

**Table S14.** Multivariate regression measuring the association of underlying factors with PMV\* (2 MET).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **PET (1 MET) ~ VP + PO + ES**  (R2 = 0.298, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 29.809524 | 0.090879 | - | 328.013 | *p* <.001 | 1.000 |
| VP | -0.268915 | 0.104564 | -0.320720494 | -2.572 | *p* <.001 | 1.308 |
| PO | 0.403494 | 0.102461 | 0.481450253 | 3.938 | *p* <.001 | 1.394 |
| ES | -0.004268 | 0.115325 | -0.005102826 | -0.037 | *p* =.971 | 2.043 |

**Table S15.** Multivariate regression measuring the association of underlying factors with PET (1 MET).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **PET (1.5 MET) ~ VP + PO + ES**  (R2 = 0.302, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 30.61079 | 0.10349 | - | 295.776 | *p* <.001 | 1.000 |
| VP | -0.33103 | 0.11908 | -0.34584478 | -2.780 | *p* <.001 | 1.308 |
| PO | 0.45073 | 0.11668 | 0.47112887 | 3.863 | *p* <.001 | 1.394 |
| ES | 0.01065 | 0.13133 | 0.01115747 | 0.081 | *p* =.935 | 2.043 |

**Table S16.** Multivariate regression measuring the association of underlying factors with PET (1.5 MET).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **PET (2 MET) ~ VP + PO + ES**  (R2 = 0.303, *p* <.001) | | | | | | |
| Variables | Unstandardized coefficients | | Standardized Coefficient | T value | p-value (*p*) | CI |
| Coefficients | Std. Error |
| (Intercept) | 31.40667 | 0.11670 | - | 269.119 | *p* <.001 | 1.000 |
| VP | -0.39269 | 0.13428 | -0.36342684 | -2.925 | *p* <.001 | 1.308 |
| PO | 0.49747 | 0.13157 | 0.46061153 | 3.781 | *p* <.001 | 1.394 |
| ES | 0.02614 | 0.14809 | 0.02424937 | 0.176 | *p* =.860 | 2.043 |

**Table S17.** Multivariate regression measuring the association of underlying factors with PET (2 MET).