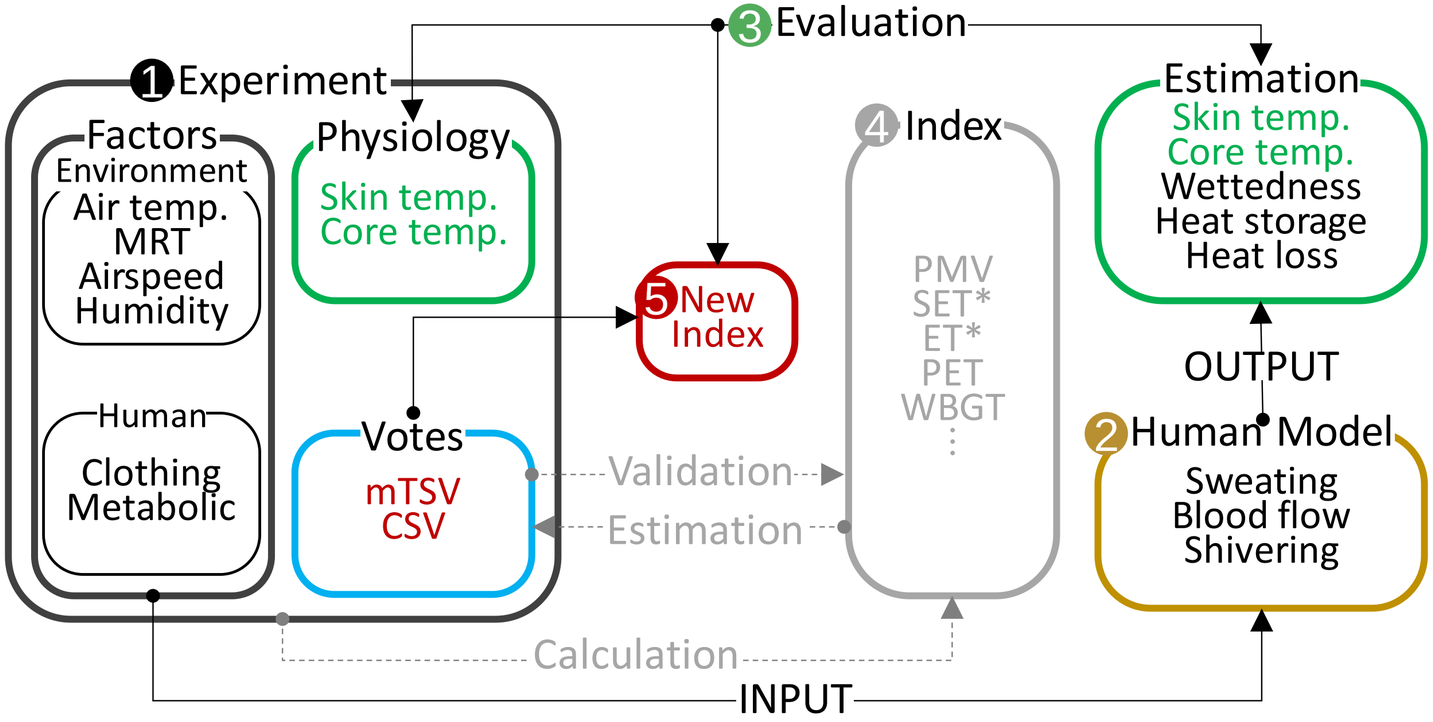
Development of a new environmental index for outdoor and mist spray environments

# Outline of research

## Background & Purpose

Proposal of a new index to evaluate the thermal sensation in outdoor and mist spray environment.

- Thermal sensation is closely related to the heat exchange between human and environment.
- Mist spray system can be used to provide thermal relief on hot outside during summer.
- Survey researches are expensive and time-consuming.
- There is no appropriate environmental index for mist spray environments.




Research flow for developing of new index

## Contents

**1 Field experiment**
- Measurement of environment factors
- Survey research (mTSV, CSV, etc.)
- Physiological responses (Temperature of skin and inside of mouth)

**2 Thermoregulation human model**
- Predict the physiological responses
- Gagge's 2 node model

**3 Physiological responses**
- Comparison of prediction and measured temps
- Estimate the thermal state of the body

**4 Existing environmental indices**
- Comparison of votes and existing indices

**5 New environmental index**
- Adopt the concept of PMV
- Calculate the heat storage by 2 node model
- Correlation of heat storage and mTSV
- Evaluate the thermal sensation in outdoor and mist spray environment



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# Thermal sensation and comfort of mist environment

## Experiment 1

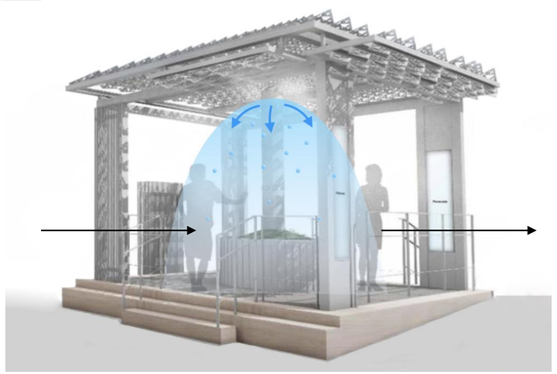
The effect of the mist spray system was verified by confirming the mTSV and CSV.

- Surveyed in before mist and after mist.
- Total of 342 women and 768 men participated in experiment freely.
- Environmental factors in mist environment were measured simultaneously

Mist spray system in Shimbashi, Tokyo

Experiment conditions

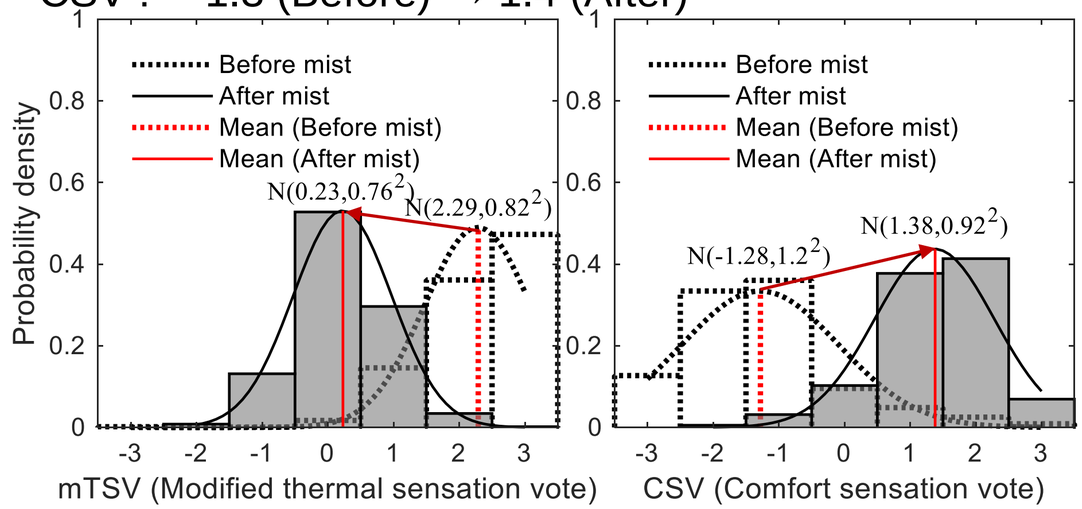
| Location | Number of Subject | Period | Mist spray: Flow rate (mL/min) | Mist spray: Mist size (μm) |
|---|---|---|---|---|
| Shimbashi, Tokyo | 1110 | Aug. 4–12, 2016 | 818–1227 | 10–20 |




The concept of experiment procedure

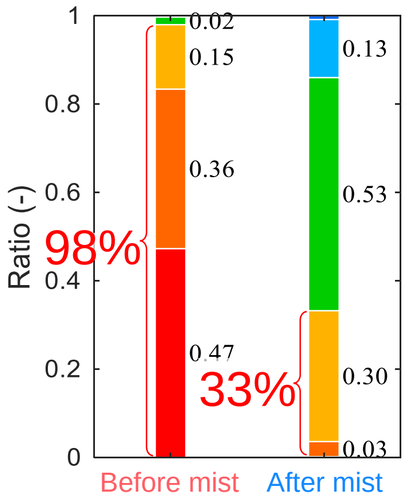
## Results

- mTSV : 2.3 (Before) → 0.2 (After)
- CSV : −1.3 (Before) → 1.4 (After)

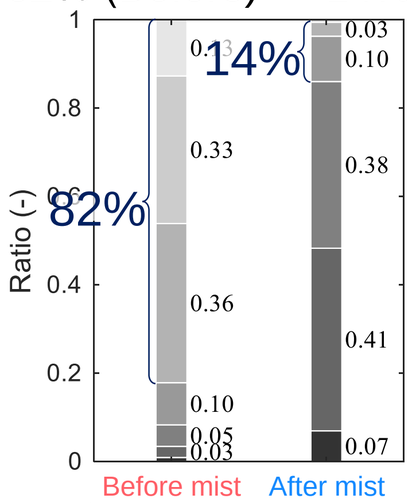



PDF of sensation vote results (mTSV & CSV)

- Feel 'Hot' : 98% (Before) → 33% (After)
- Feel 'Discomfort' : 82% (Before) → 14% (After)




The ratio of mTSV




The ratio of CSV

mTSV Scale
- mTSV( 3): Very Hot
- mTSV( 2): Hot
- mTSV( 1): Slightly Hot
- mTSV( 0): Neutral
- mTSV(-1): Slightly Cold
- mTSV(-2): Cold
- mTSV(-3): Very Cold

CSV Scale
- CSV( 3): Very Comfort
- CSV( 2): Comfort
- CSV( 1): Slightly Comfort
- CSV( 0): Neutral
- CSV(-1): Slightly Discomfort
- CSV(-2): Discomfort
- CSV(-3): Very Discomfort



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# Thermoregulation human model: evaluation and verification

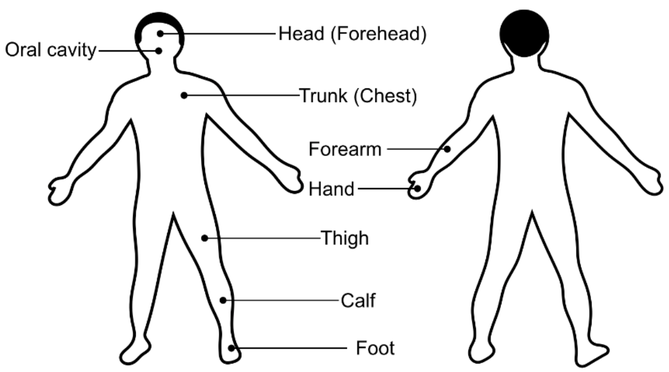
## Experiment 2

Field experiment has been conducted to verify whether Gagge's 2-node model can be applied to the outdoor and mist spray environments.

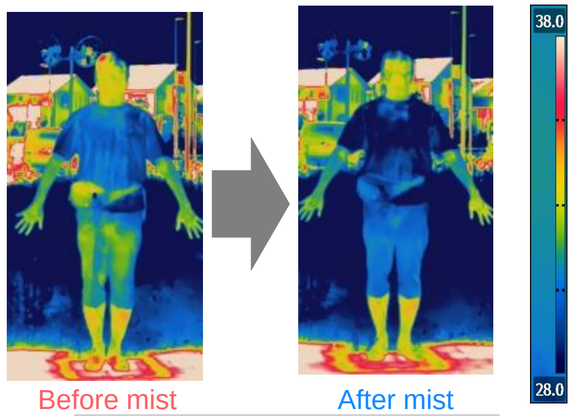

Mist spray system in Fujisawa, Kanagawa

Irradiation meters

Subjects in experiment




Measurement points




Infrared thermography

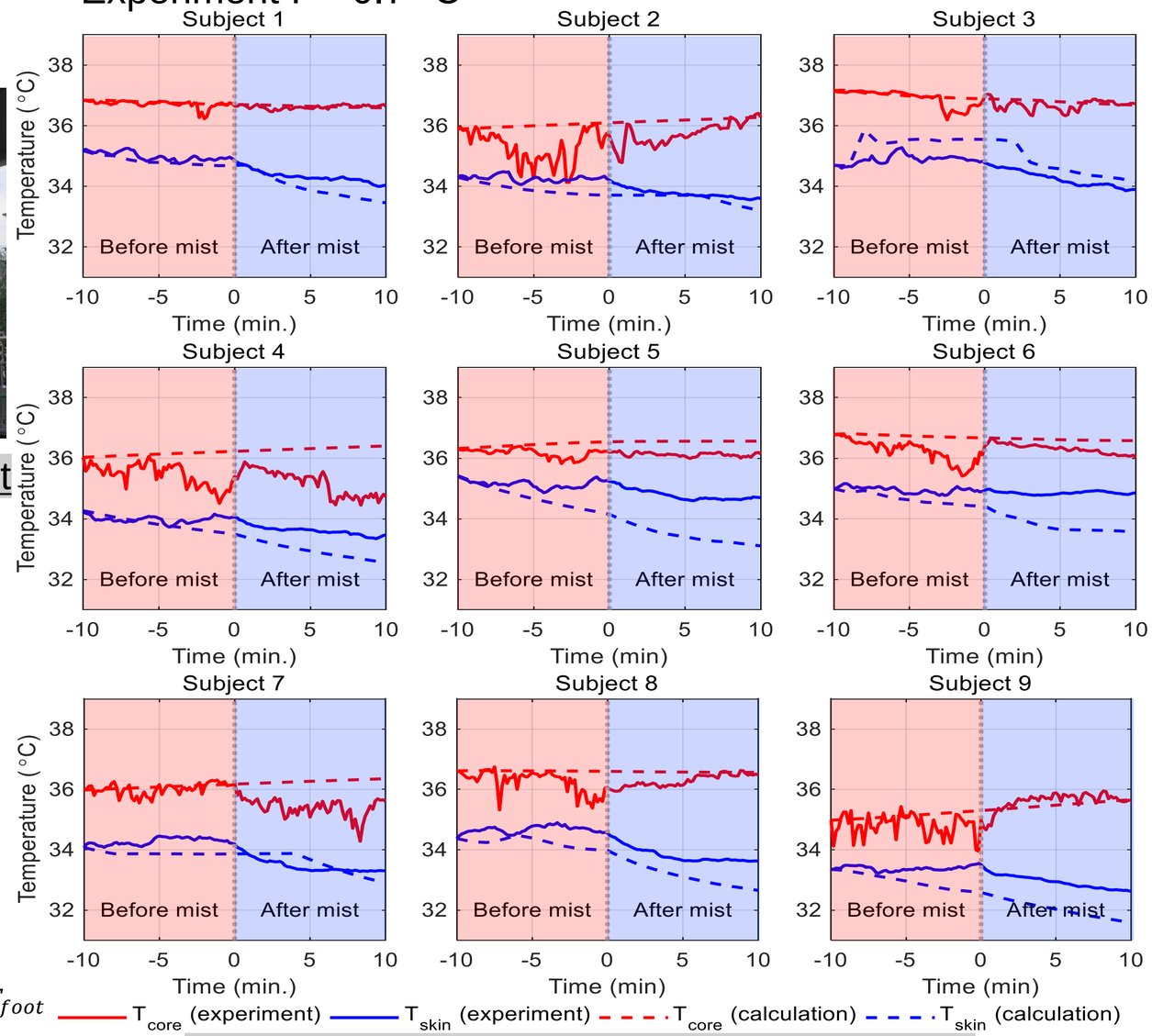
$$T_{sk} = 0.07\,T_{head} + 0.35\,T_{trunk} + 0.14\,T_{forearm} + 0.05\,T_{hand} + 0.19\,T_{thigh} + 0.13\,T_{calf} + 0.07\,T_{foot}$$

$$T_{\mathrm{core}} \approx T_{\mathrm{mouth}}$$

## Results

Mean skin temperature change in mist environment

- Calculation by 2 node model : −1.0 °C
- Experiment : −0.7 °C




Mean skin temperature and core temperature



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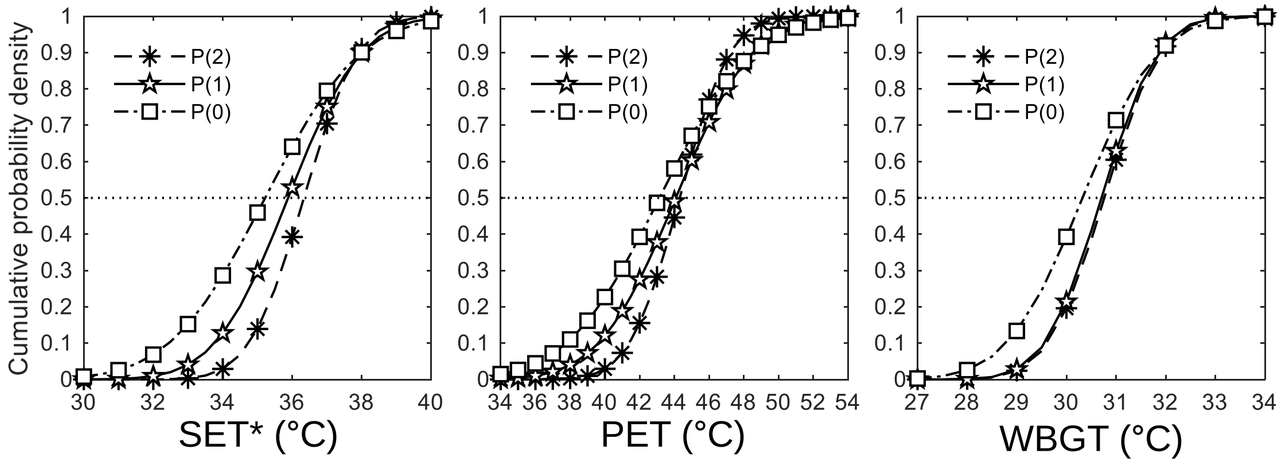
# Proposal of a new index using thermal sensation votes

## mTSV vs. existing environmental indices

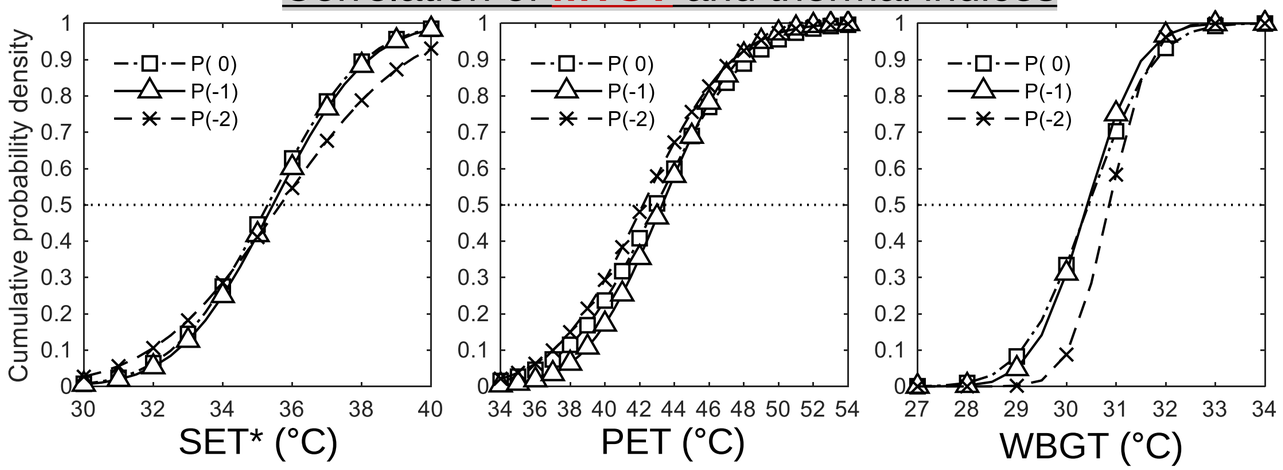
Only SET* might be able to predict the mTSV in mist spray environment.

Existing environmental indices are difficult to be utilized for predicting the thermal comfort.




P(2) = mTSV (≥ 2), P(1) = mTSV (≥ 1), P(0) = mTSV (≥ 0)

Correlation of **mTSV** and thermal indices




P(0) = CSV (≤0), P(−1) = CSV (≤−1), P(−2) = CSV (≤−2)

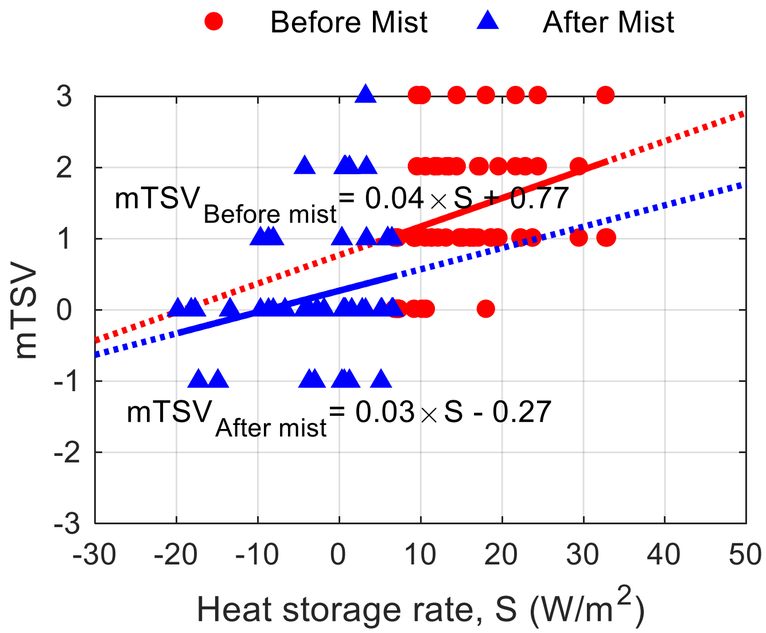
Correlation of **CSV** and thermal indices

## New index: O-PMV

Adopting concept of PMV, propose a new environmental index O-PMV, by using the correlation between mTSV and the rate of heat storage.

$$\mathrm{PMV} = \frac{\delta TSV}{\delta S} \times S\ , \quad \mathrm{O-PMV} = \frac{\delta mTSV}{\delta S} \times S$$

PMV: predicted mean vote, O − PMV: outdoor predicted mean vote
$S$: the rate of heat storage ($\mathrm{W/m^2}$), TSV: thermal sensation vote
mTSV: modified thermal sensation vote




Correlation between rate of heat storage and mTSV (10 minutes exposure)

O-PMV = 0.04 × $S$ + 0.77 (Before mist)

O-PMV = 0.03 × $S$ − 0.27 (After mist)



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