Adaptive Behaviours and Outdoor Thermal Comfort:
A Multi-Agent System Approach Incorporating Social Archetypes

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Urban microclimate, Agent-based modelling, Social resilience

BACKGROUND

In tropical cities, thermal comfort is a critical concern in urban planning, as rising heat can discourage outdoor activity and limit social engagement. However, urban heat does not affect populations equally. Different groups of people, e.g., the elderly or those with limited mobility, require tailored interventions. Understanding how these groups can safely adapt to outdoor heat may increase social interaction and enhance social resilience.

Research framework

This study integrates urban microclimate simulations with a multi-agent system (MAS) modelling that incorporates archetypes – groups of people with distinct characteristics, based on the similarities in their physiological, perceptual, and socio-behavioural attributes. Each archetype is programmed as a virtual pedestrian (agent) that collects heat exposure data along its route.

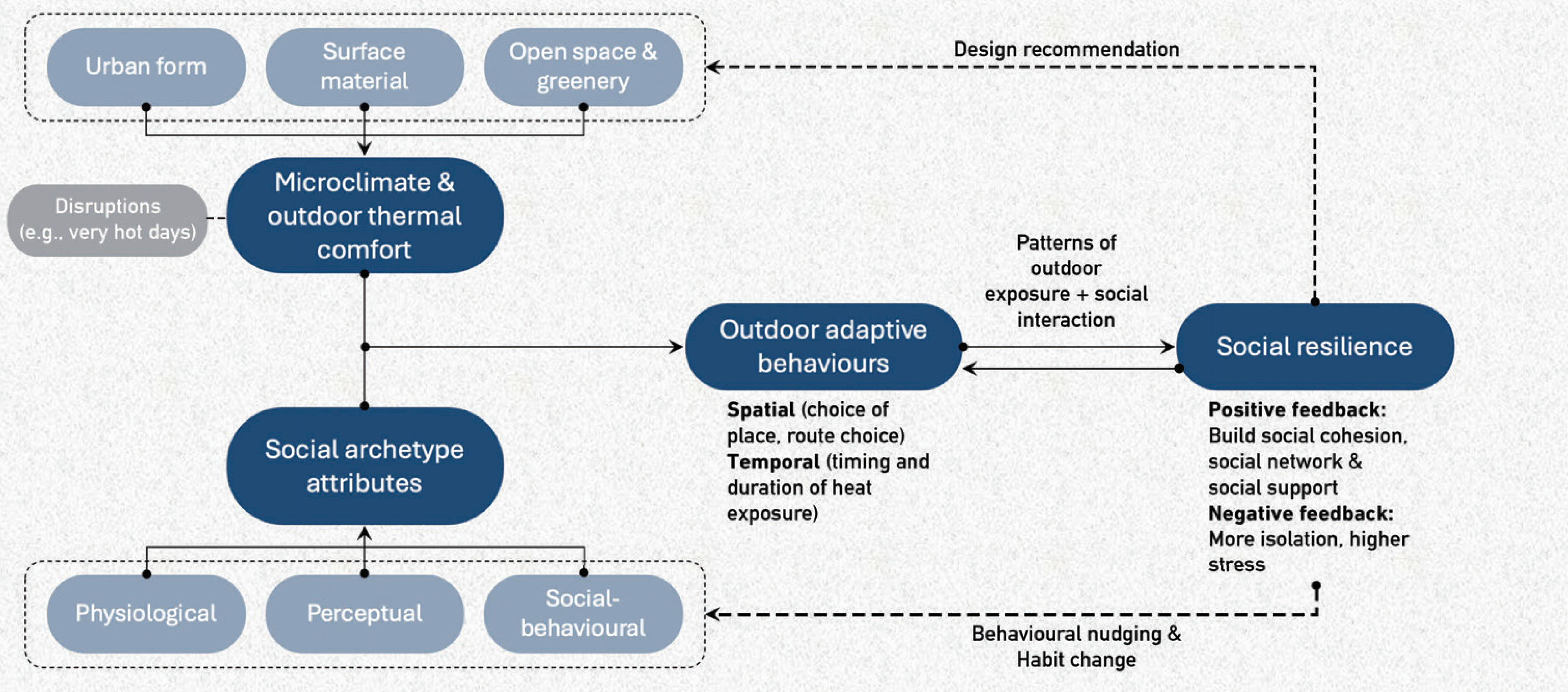

Fig 1. Conceptual framework linking urban microclimate, social archetypes, adaptive behaviour and social resilience.

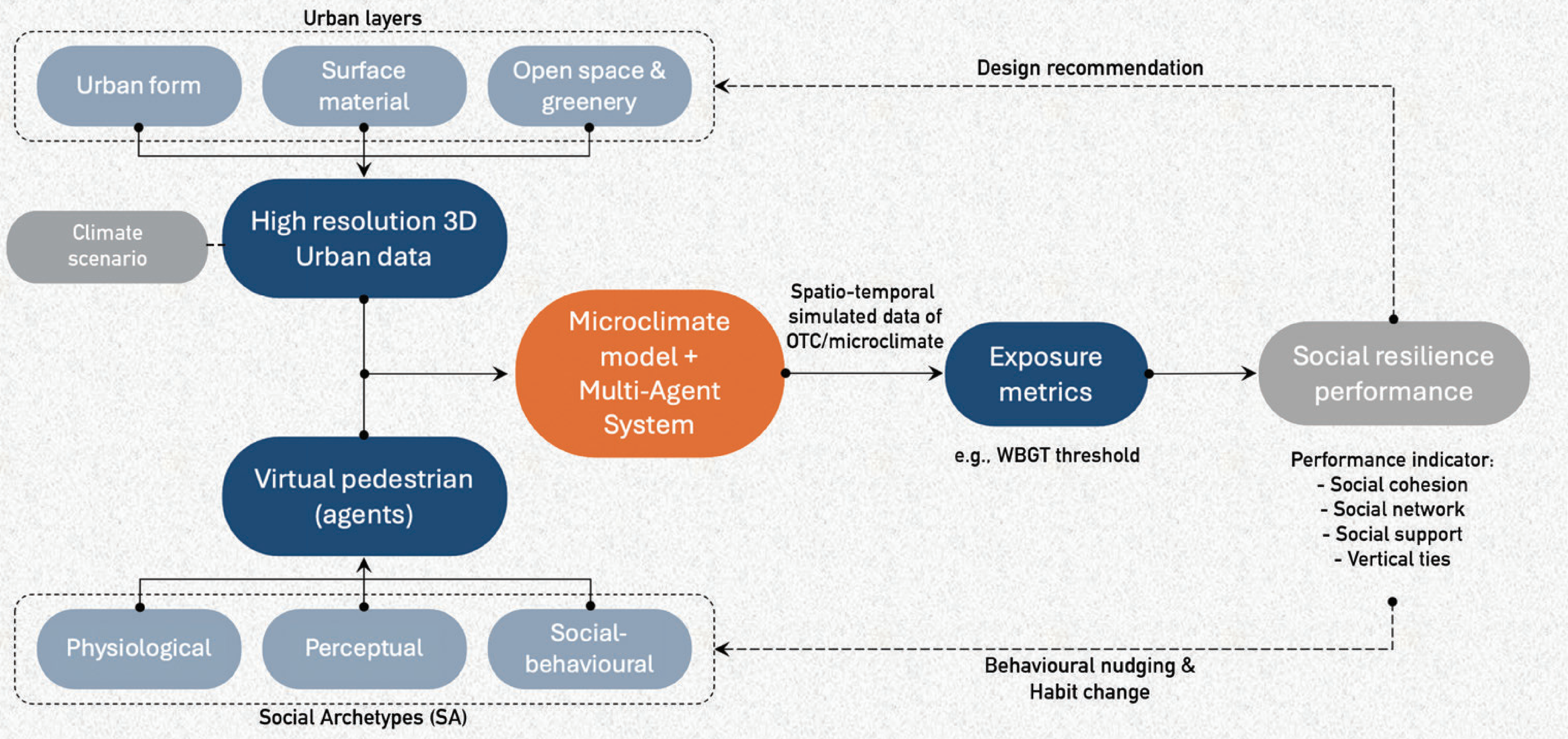

Fig 2. Modelling approach combining high-resolution urban data with detailed social-behavioural attributes.

METHOD

- Within the population, heat vulnerability may be influenced by a person's general health and fitness, reflected in physiological measures such as walking speed.
- Older adults are at greater risk of experiencing adverse effects from prolonged heat exposure.

Fall risk	Average walking speed (m/s)	No. of participants
Low (<64)	1.05	12
Medium (64-100)	0.99	4
High (>100)	0.81	4
Healthy adult [2]	1.14	-

Table 1. Average walking speed among elderly participants.

- Representative average walking speeds are taken from a study with older adults who have varying degrees of fall risk.
- These are used to classify four archetypes: healthy adults, and those with low, medium, and high risk of falls.

- Heat exposure is simulated using an urban microclimate model, coupled with a Multi-Agent System, for an actual case study in Singapore.
- Heat-stress index, Wet Bulb Globe Temperature (WBGT), is calculated using a simplified empirically derived formula[3].

Fig 3. Microclimate simulation domain at Bishan Park, Central Singapore. High-resolution urban data is used as the static layer.

References

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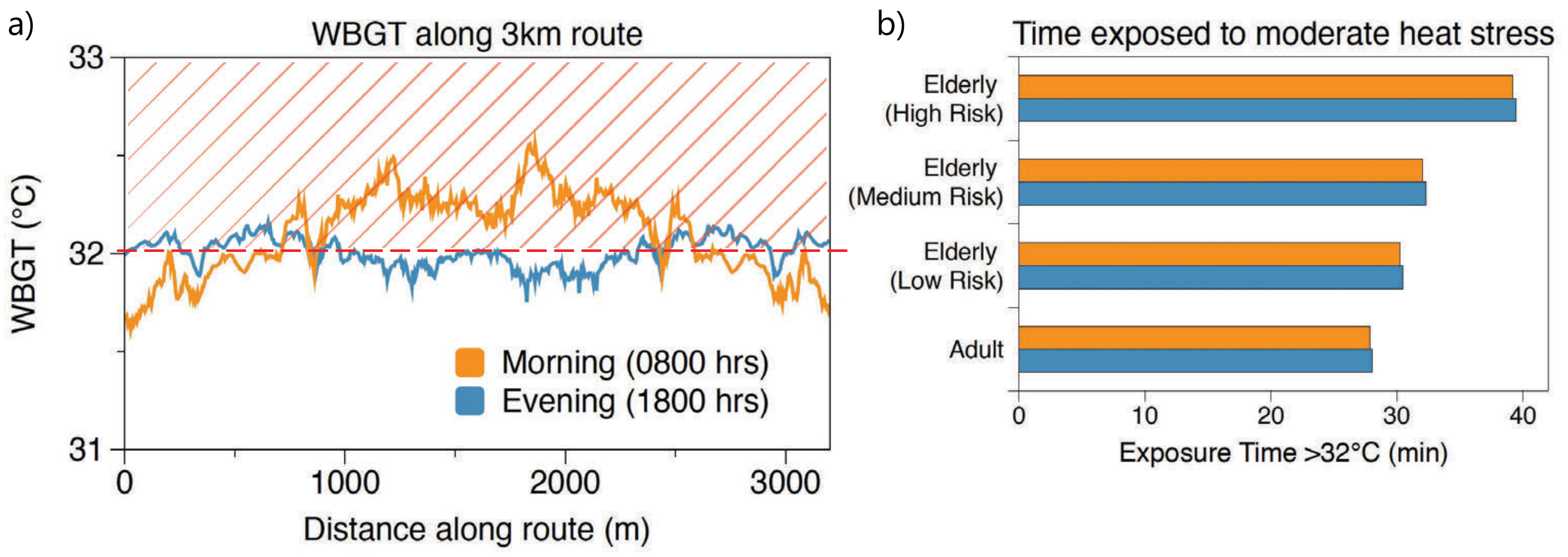
PRELIMINARY FINDINGS

- During hot days, different archetypes experience varying durations of moderate heat stress (>32 °C)[4].
- While exposure duration to moderate heat stress is similar between morning and evening across all groups, morning periods tend to experience higher heat stress intensity, especially in park areas.



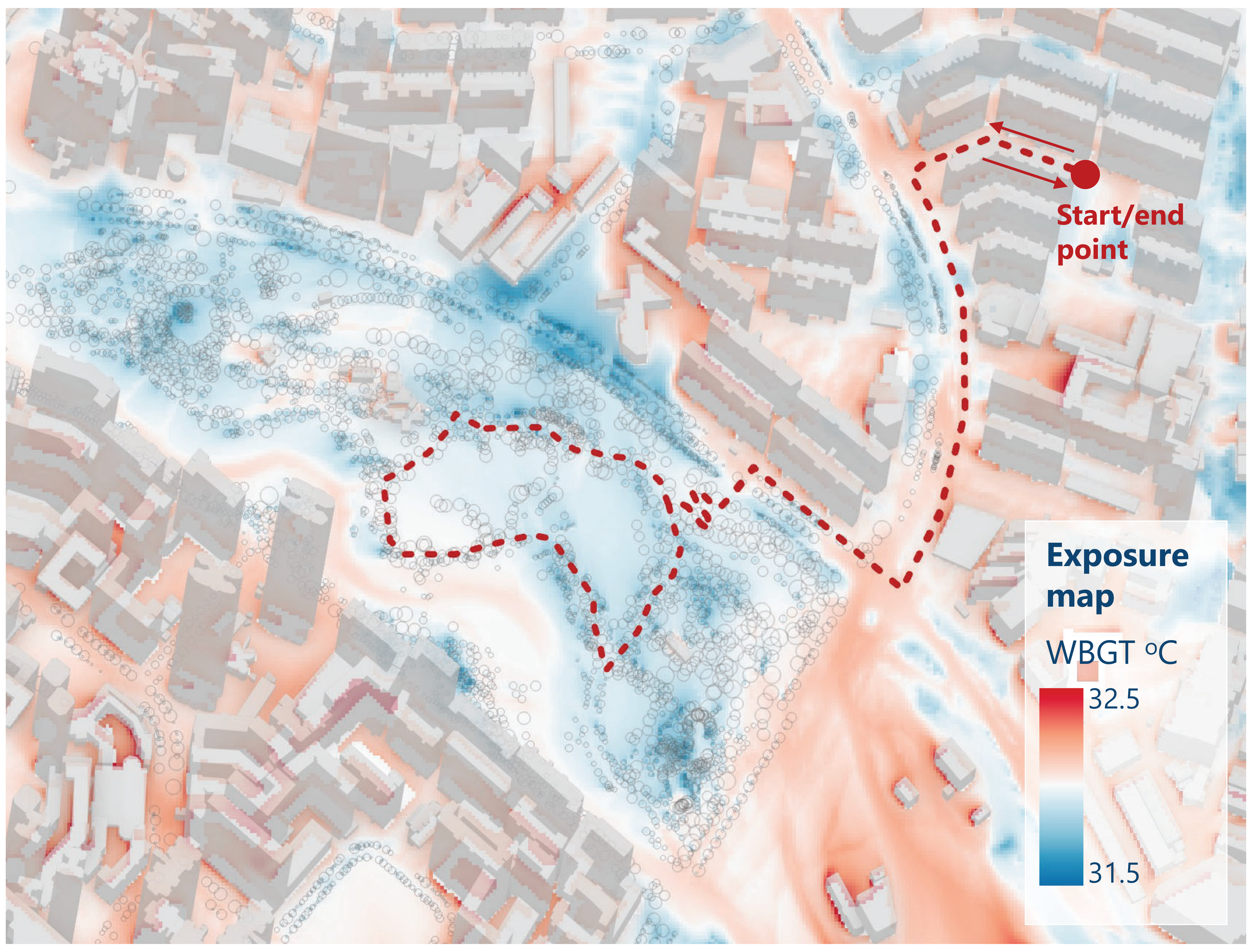


Fig 4 (above). Exposure map showing WBGT in the evening (1800 hrs), with a red dashed line indicating the ~3km loop from a residential estate to Bishan Park. The grey circles represent the existing trees.

Fig 5 (left). Disparities in WBGT exposure time between different demographics. (a) WBGT along a ~3km route from a residential estate to Bishan Park and back (route shown in Fig. 4). (b) Total time an individual is exposed to moderate heat stress (>32°C WBGT) along the route.

Next step

- Incorporate Social Archetypes, rather than purely demographic and physiological attributes, into the model and analyse the social resilience performance.
- Improve the heat-stress index calculation method[5] and validate the results against the measurement data.

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