Modulation of pedestrian velocity along curves: a comparison between dyads and individuals

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Abstract This study investigates how pedestrians adjust their velocity along curved trajectories, comparing individuals and dyads. By analysing ecological data from the DIAMOR underground pedestrian street network, we aim to determine whether dyads exhibit different velocity patterns compared to individuals along curved paths. Our findings indicate dyads begin to reduce their velocity when encountering higher curvature values as compared to individuals, and at very high curvature values, their velocity profile aligns increasingly closely with that of individuals.

Keywords Pedestrian dynamics, social groups, pedestrian behaviour, curvature

Groups, particularly groups of two (dyads), serve as a fundamental building block of pedestrian crowds and influence both local and large-scale movement patterns [1]. Studying dyads is essential for understanding pedestrian behaviour in various contexts, such as evacuation scenarios, urban planning, and crowd management.

Understanding how pedestrians adjust their velocity when navigating curves is crucial for modeling human movement and designing pedestrian-friendly environments. Unlike walking in straight paths, curved trajectories introduce additional biomechanical and perceptual challenges that influence trajectory planning. While previous research explored how individuals regulate speed based on curvature [2, 3] the effect of social factors such as walking in pairs remains less understood. Social interactions, spatial constraints, and coordination between partners may influence their walking speed, when adapting to curved paths.

This study investigates how pedestrians modulate their velocity along curved trajectories, comparing individuals and dyads. Analysing ecological trajectories, we aim to determine (i) whether dyads exhibit different velocity patterns compared to individuals and (ii) how curvature influences these adjustments.

Trajectories were collected from uninstructed pedestrian movement data recorded in the DIAMOR underground facility, in Japan. *Passage points* (i.e., the locations where pedestrians entered and exited the recording area) were identified in the environment and all dyad and individual trajectories traversing between two passage points were studied.

For each pair of passage points, we computed a *reference trajectory* for both dyads and individuals. The reference trajectory was defined as the average path taken by all individuals (resp. dyads) between the two passage points (see Figure 1).

Curvature and velocity were calculated along these reference trajectories (see Figure 2). Velocity-curvature relationship between dyads and individuals is contrasted to identify differences in speed regulation.

A log-log plot of velocity versus curvature revealed that at low curvature, pedestrians maintain a relatively stable velocity, while at higher curvature, velocity decreases (see Figure 3). This pattern suggests a threshold effect, where only sufficiently sharp turns require notable speed adjustments. Dyads consistently exhibited lower velocities than individuals, which may be attributed to social coordination, such as maintaining mutual awareness and synchronization. We can explain these findings by assuming a delicate balance between the attention that dyad members can allocate to social interaction and the demands of walking. Namely, they must divide their energy between engaging in social interactions and

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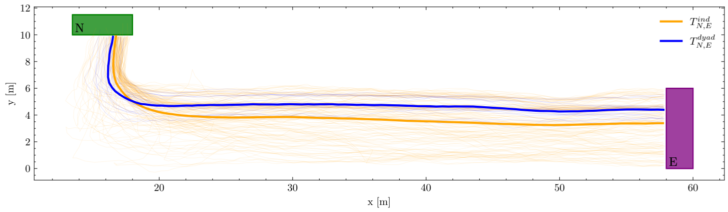

Figure 1: Reference trajectories for dyads and individuals between two passage points. Reference trajectories are showed with the thicker line, and the original trajectories are shown with the thinner lines.

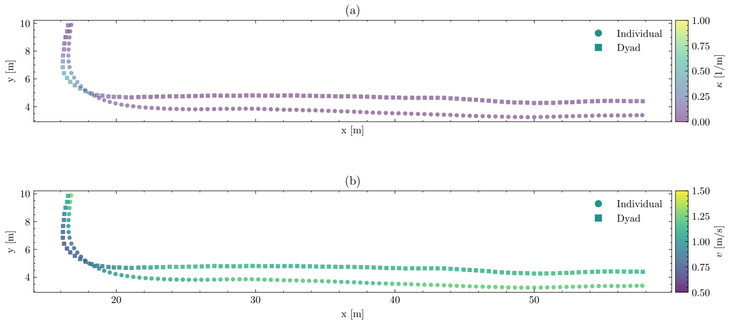

Figure 2: (a) Velocity and (b) curvature values along the reference trajectories of dyads and individuals.

navigating their surroundings, particularly when traversing curved paths. As the curvature of the path increases, walking becomes more challenging. This reflects on individuals as a decrease in velocity as soon as curvature starts increasing. In the case of dyads, they can maintain a steady pace even as the curvature increases by reallocating their energy from social interaction to walking, but only until their velocity matches that of individuals navigating similar curves. Once the dyads' speed aligns with that of the individuals, it indicates that they have reached their limit, necessitating a reduction in their velocity.

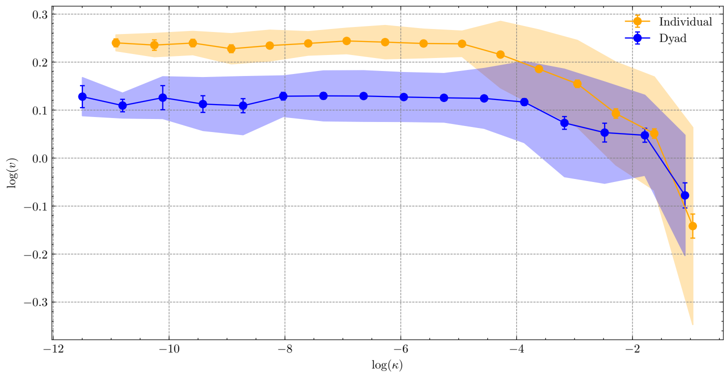

Figure 3: Log-log plot of velocity versus curvature for dyads and individuals.

These findings provide insight into how pedestrians regulate their speed in response to curvature, with implications for pedestrian dynamics modeling and urban planning. A next step is to examine how the inner and outer pedestrians within a dyad adjust their velocities differently, as their relative positions may influence movement coordination and speed regulation.

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