Metrics for describing dyadic joint movement

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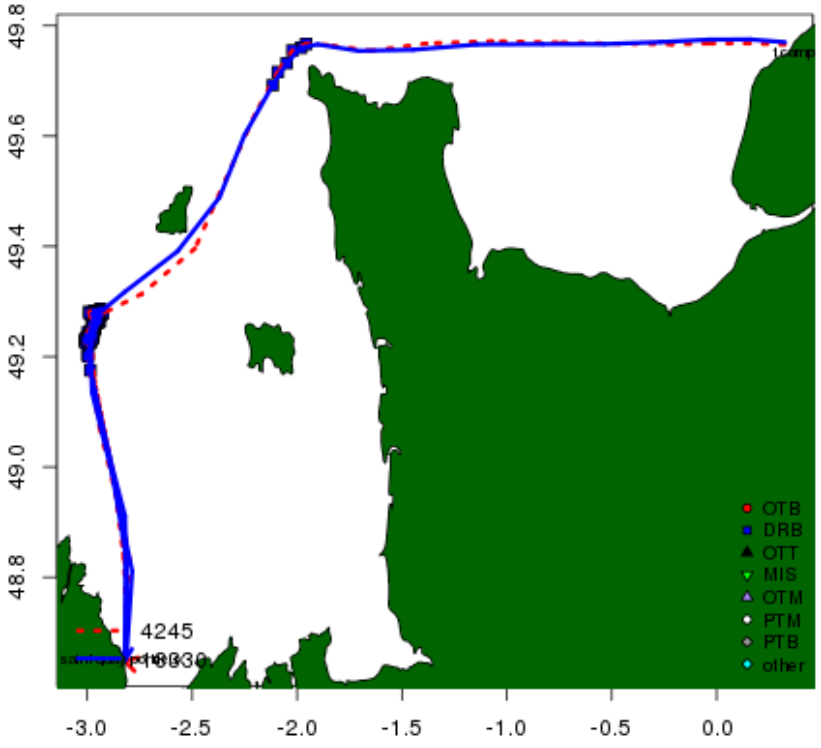
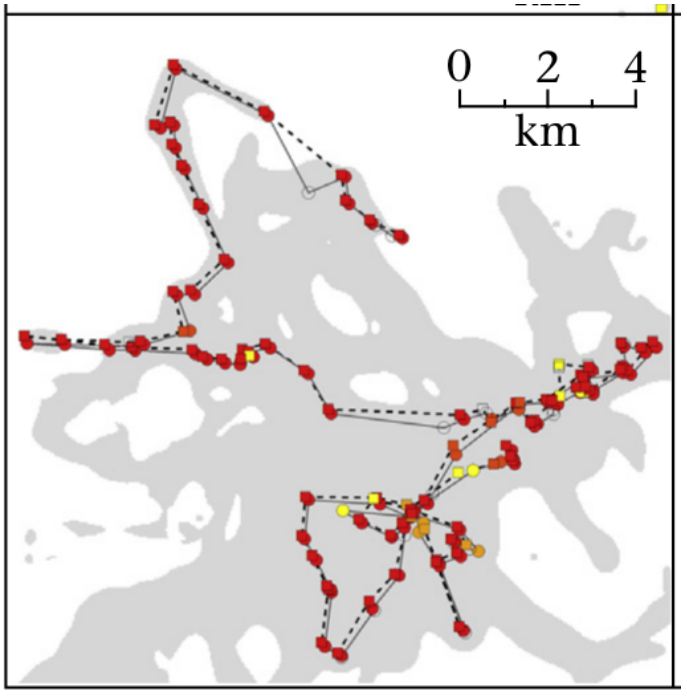
Introduction

- How to assess joint movement in tracking data?
- Start simple: dyadic movement



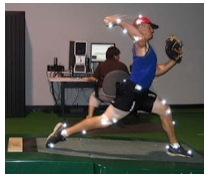
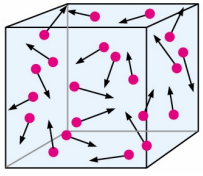
Fishing vessels
(unpublished)



African lions
(Benhamou et al 2014)

Metrics

From animal ecology, sports, medicine, physics, psychology, music, etc.:

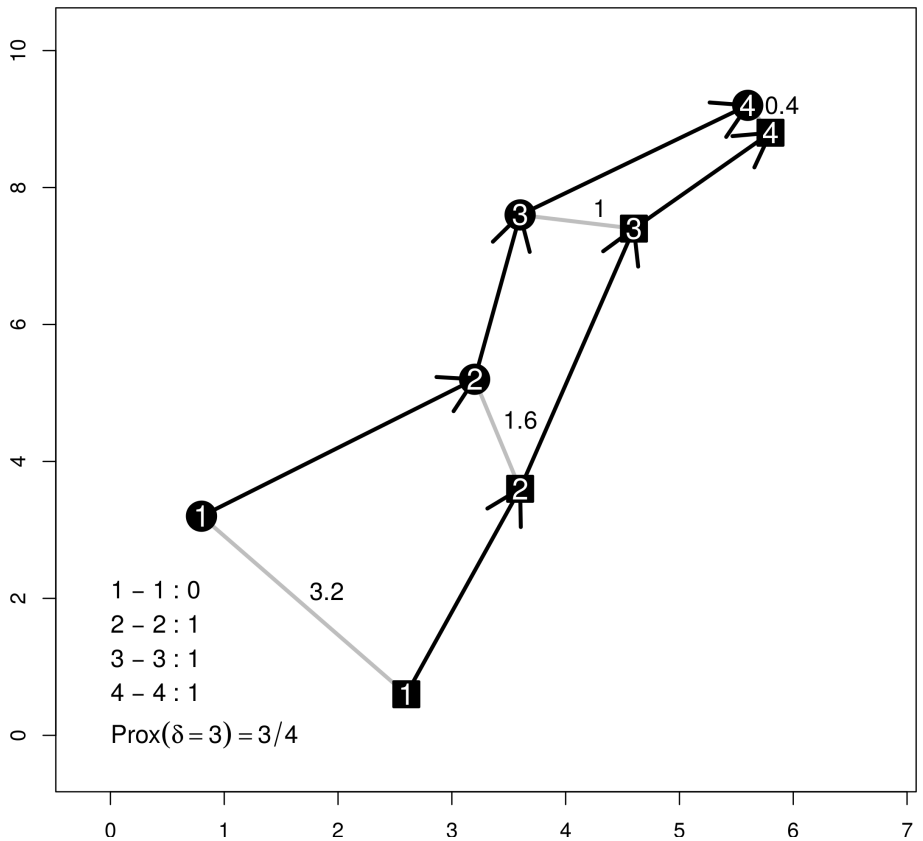
- Prox: proximity index (Bertrand et al. 1996)
- Cs: coefficient of sociality (Kenward et al. 1993)
- HAI: half-weight association index (Brotherton et al. 1997)
- Lixn: coefficient of interaction (Minta 1992)
- jPPA: joint potential path area (Long et al. 2015)
- CSEM: cross sampled entropy (Richard and Moorman 2000)
- r: correlation
- DI_d, DI_θ, DI: dynamic interaction indices (Long and Nelson 2013)

Prox: proximity index

$$Prox = \left(\sum_{t=1}^{T} K_\delta(t) \right) / T$$

$$K_\delta(t) = \mathbb{1}_{\{\|A_t - B_t\| < \delta\}}$$

- proportion of simultaneous fixes that are proximal
- min: 0 (no proximity)
- max: 1 (always close)
- Issue: δ

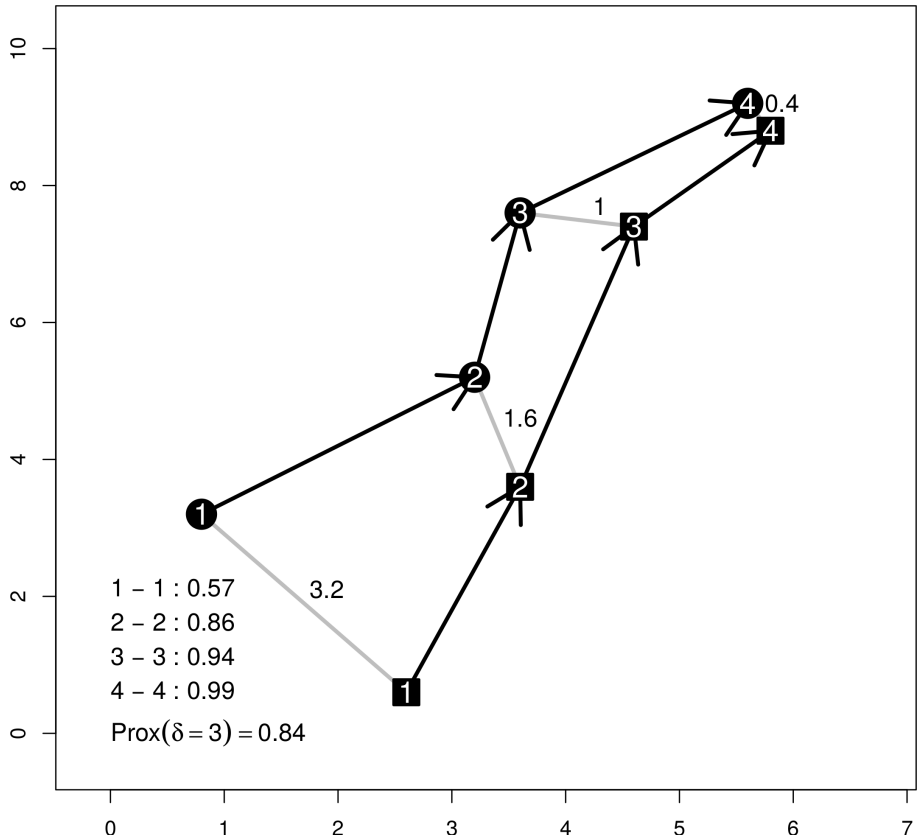


Prox: proximity index

$$Prox = \left(\sum_{t=1}^{T} K_\delta(t) \right) / T$$

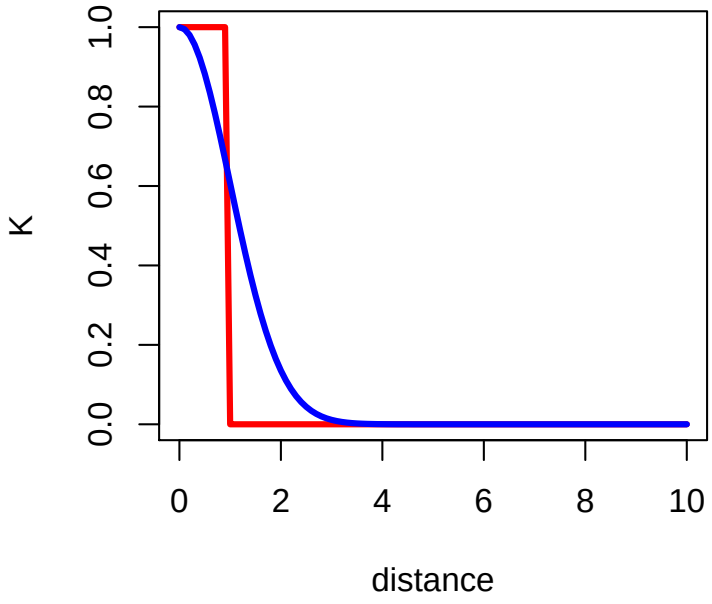
$$K_\delta(t) = \exp\left(-\|A_t - B_t\|^2 / (2\delta^2)\right)$$

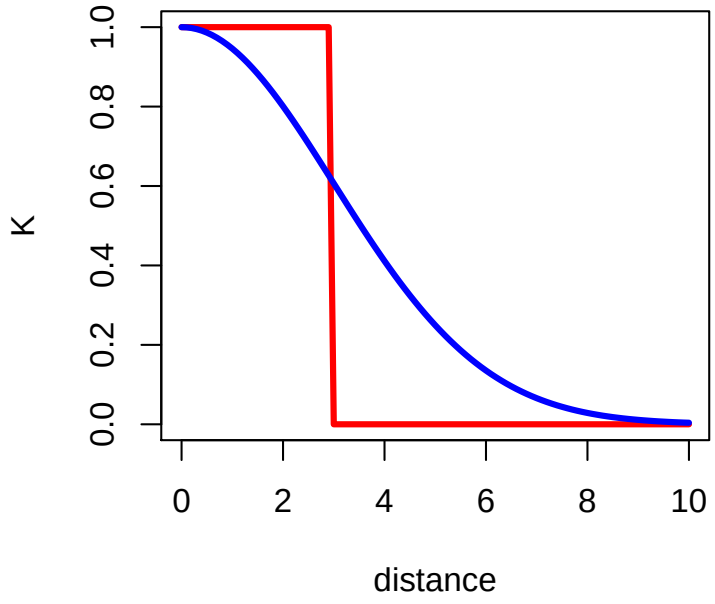
- smoothed function of proximity
- min: 0 (no proximity)
- max: 1 (always close)
- Issue: δ



Prox: proximity index

Comparing $K^1_\delta(t) = \mathbb{1}_{\{\|A_t - B_t\| < \delta\}}$ and
$K^2_\delta(t) = \exp\left(-\|A_t - B_t\|^2/(2\delta^2)\right)$ for $\delta = \{1, 3\}$





K^1 is easier to interpret; K^2 is continuous, monotonic and smoother

Other kernels are possible!

r: correlation

r: Pearson or Spearman correlation (e.g. speed, lon, lat)

- min: -1 (opposition)
- max: 1 (coordinated movement)

DI, DI_d and DI_θ: dynamic interaction indices

DI: dynamic interaction

- Displacement:

$$g_t = 1 - \left(\frac{\mid d_t^A - d_t^B \mid}{d_t^A + d_t^B} \right)^\delta$$

DI_d: mean(g_t)

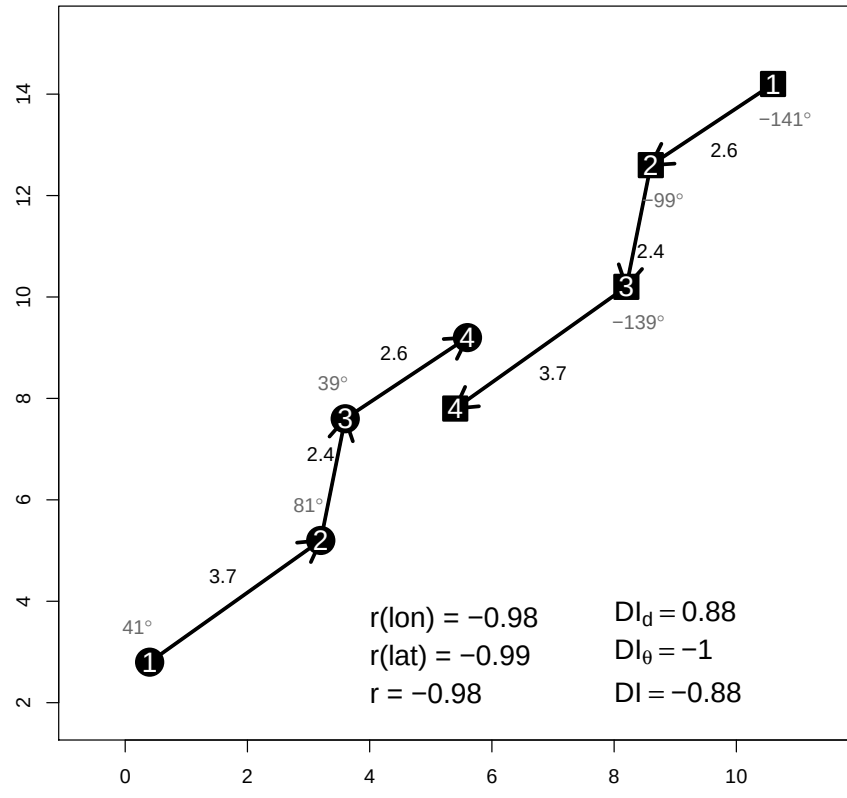
  - min: 0 (no coord.)
  - max: 1 (perf. coord.)

- Azimuth:

$$f_t = \cos(\theta_t^A - \theta_t^B)$$

DI_θ: mean(f_t)

  - min: -1 (opp. direct.)
  - max: 1 (same orient.)

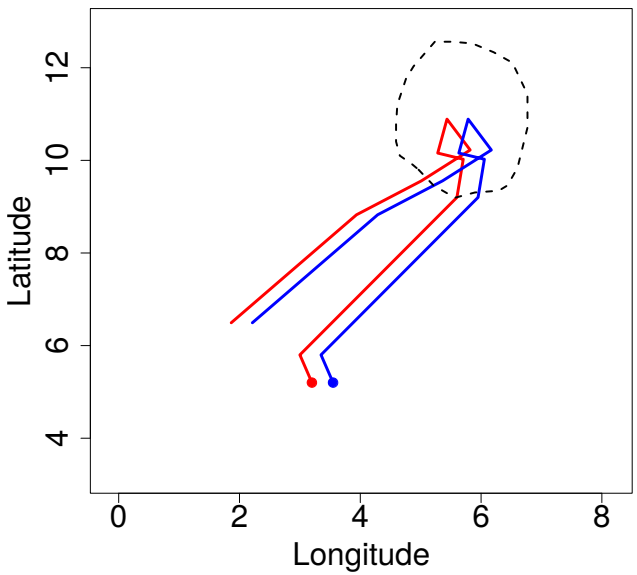


DI: mean($g_t \times f_t$)

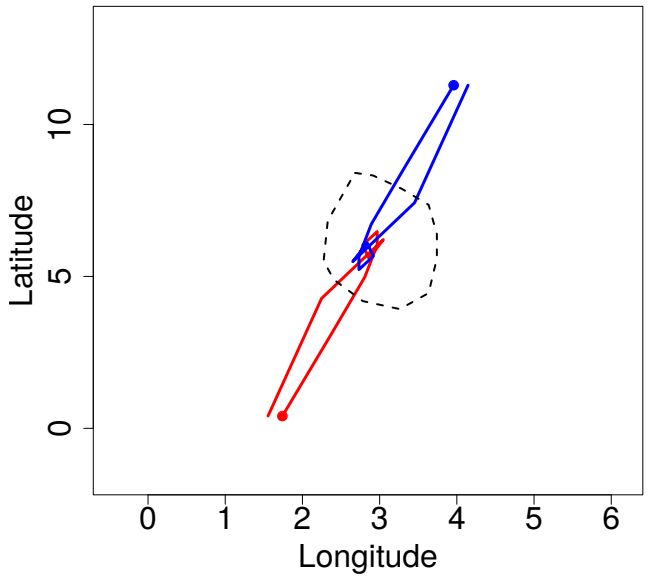
- min: -1 (opposed mov.)
- max: 1 (cohesive mov.)

Case scenarios

Evaluating contrasting case scenarios:
e.g. generating arbitrary trajectories with



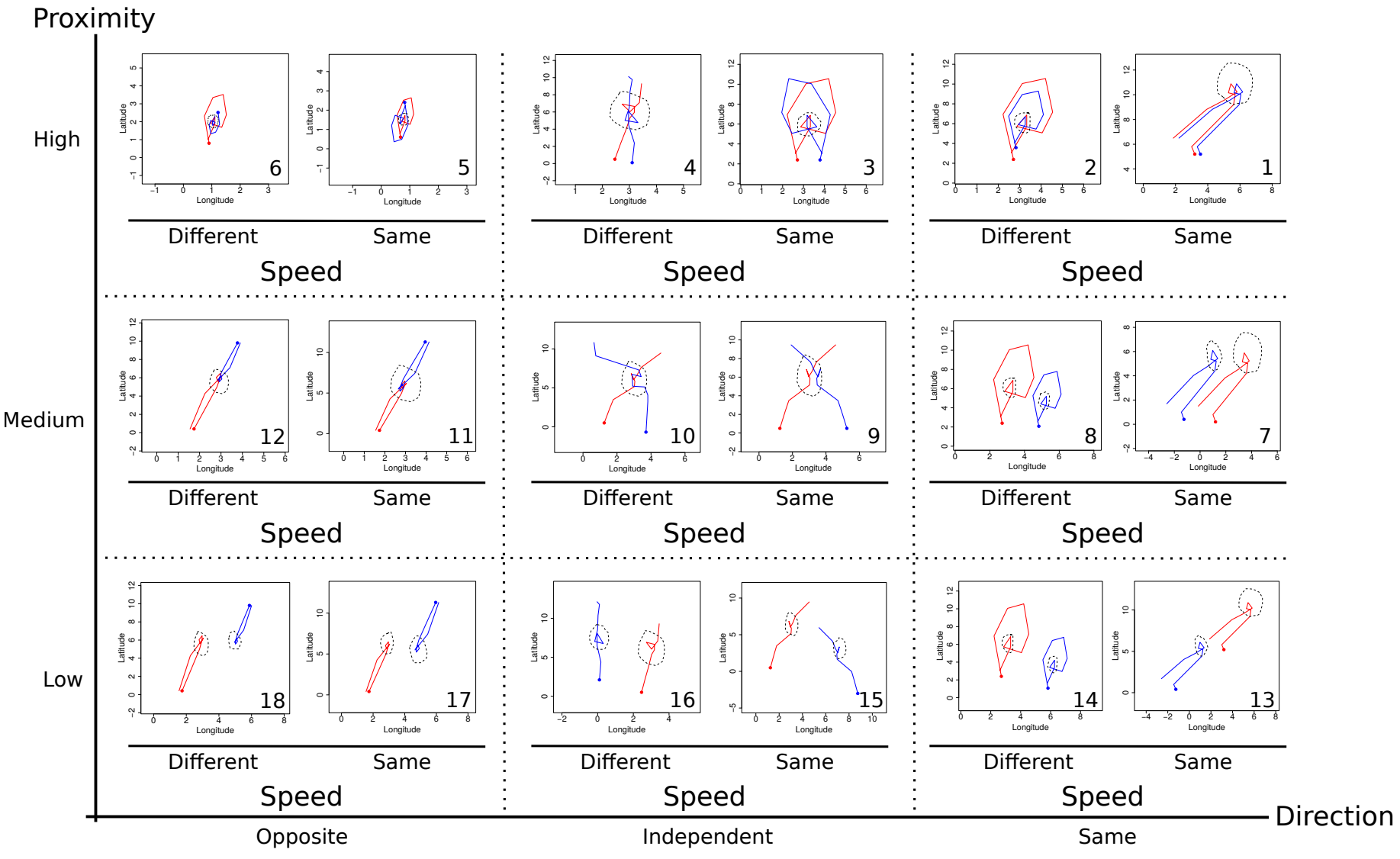
High proximity, high coordination in direction and speed



Some proximity, opposite directions, same speed

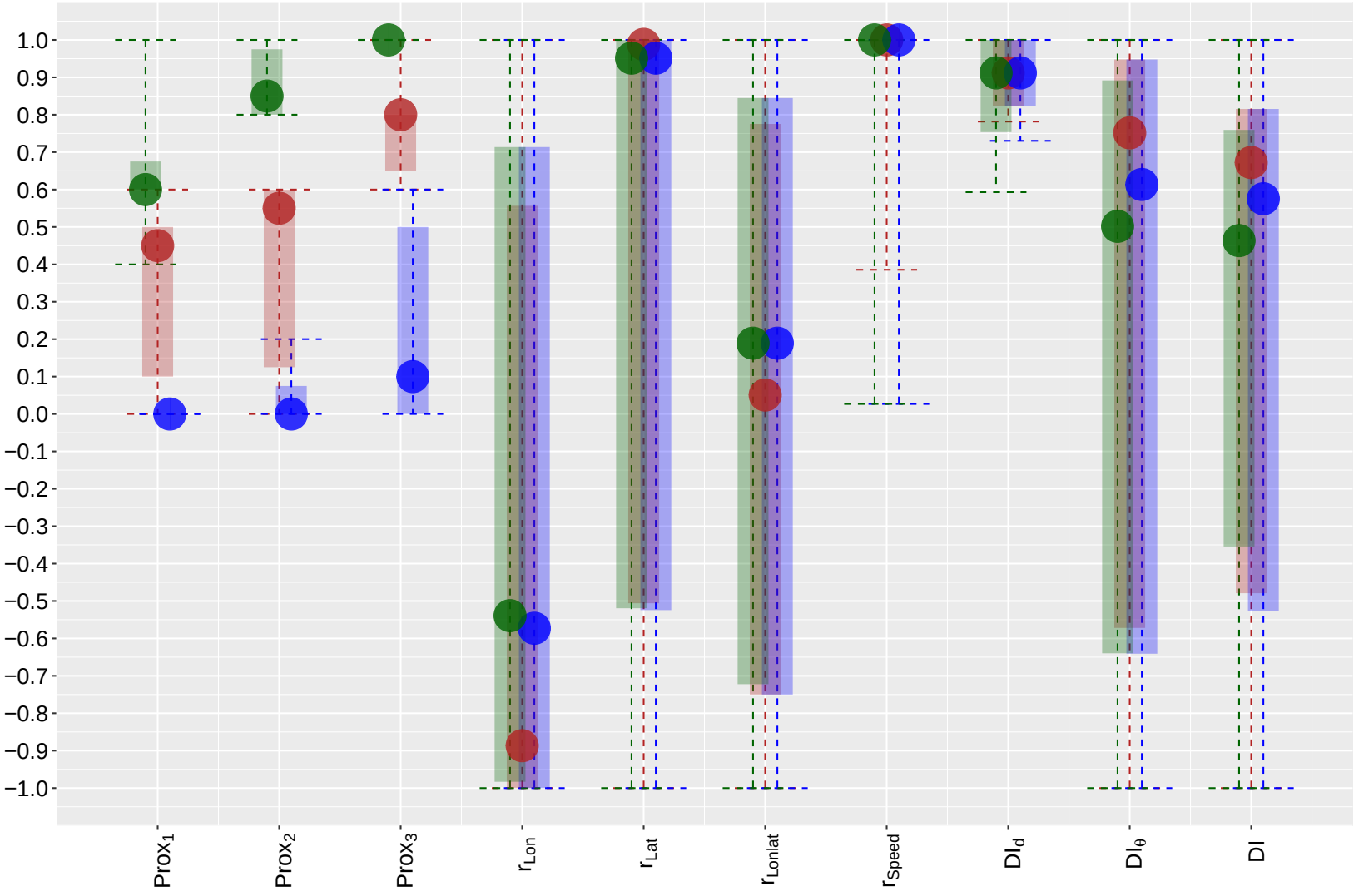
Case scenarios

Evaluating **18** contrasting scenarios



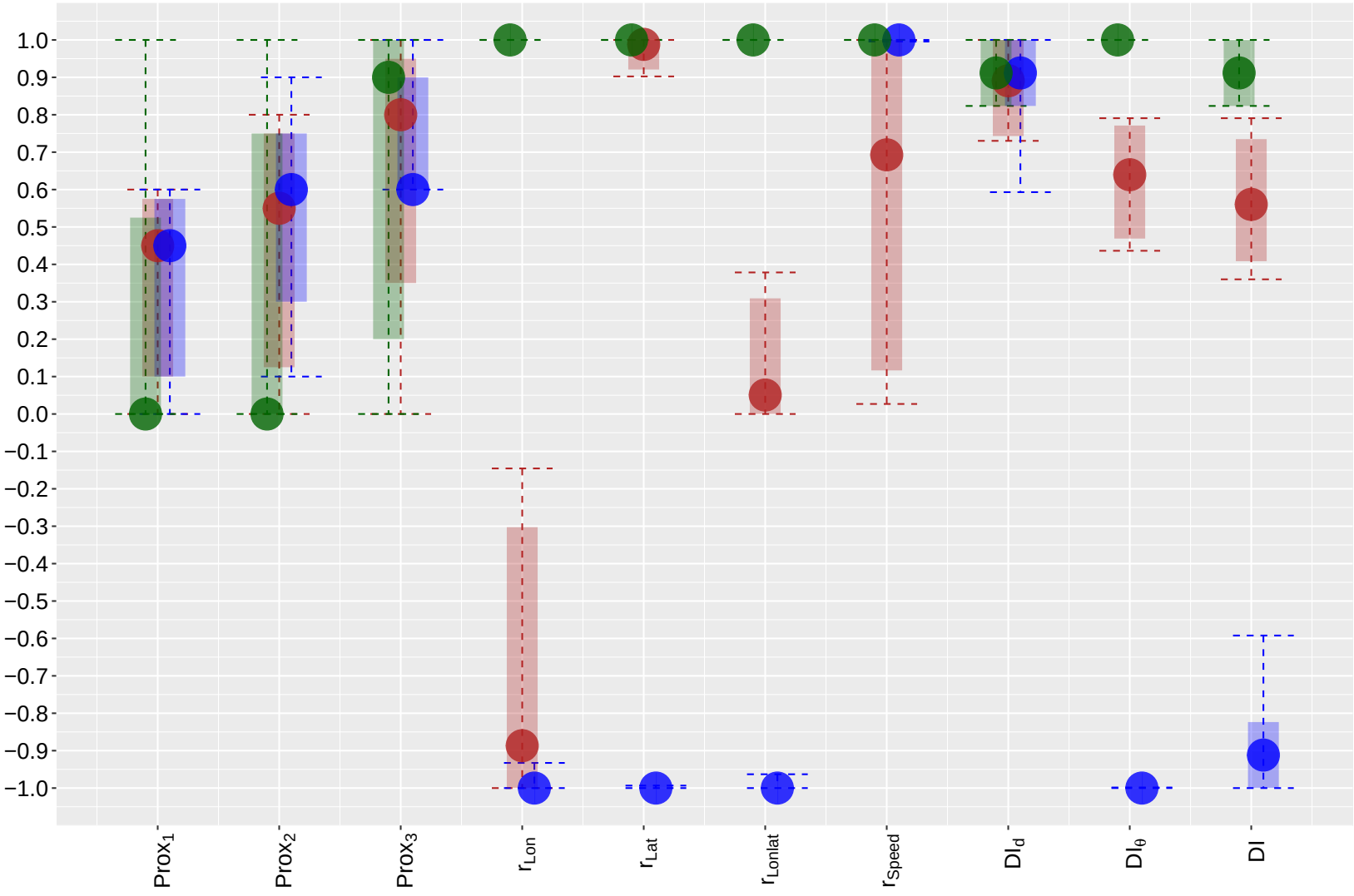
Case scenarios

For contrasting scenarios in proximity: high (green), medium (red), low (blue)



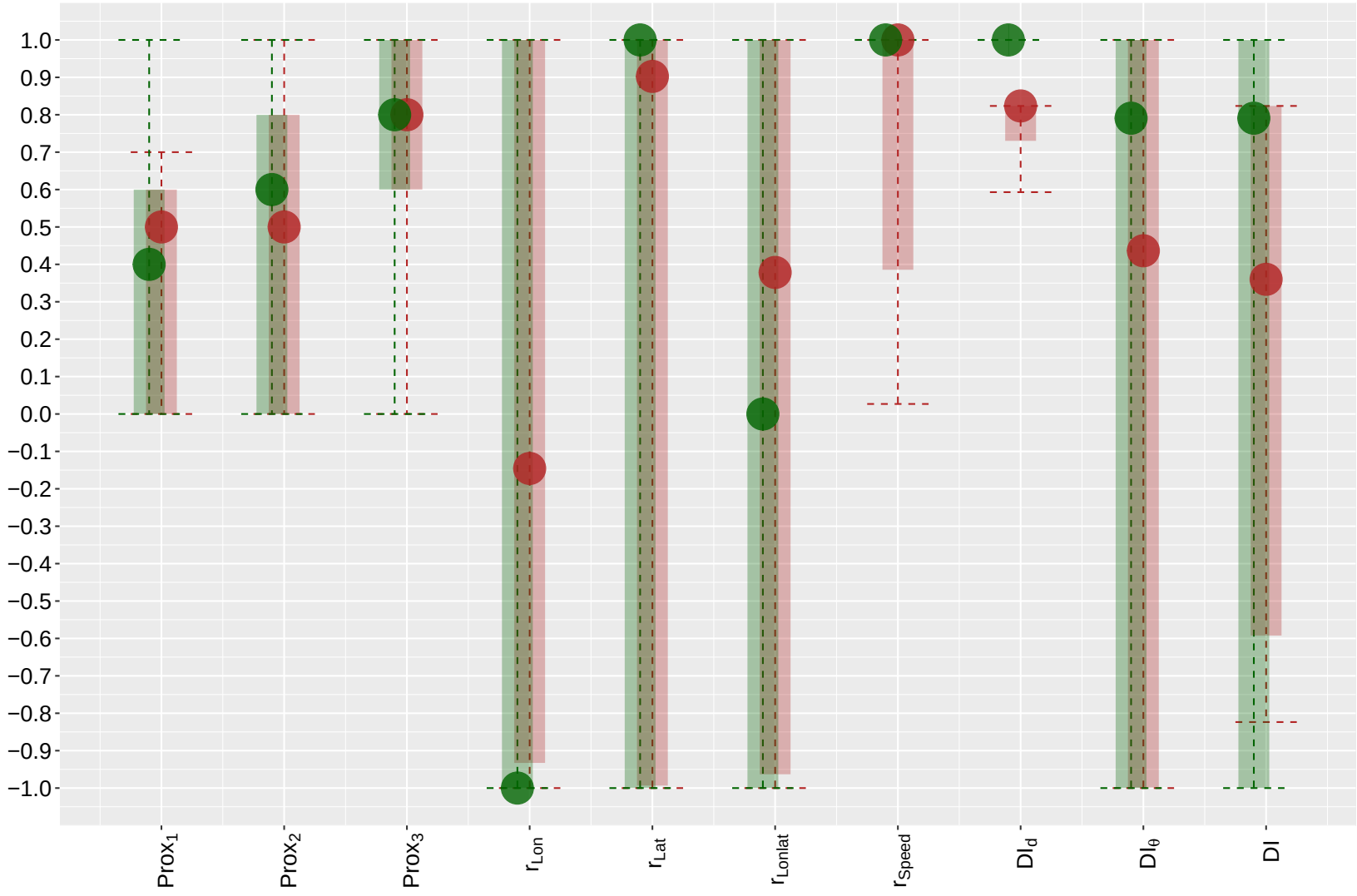
Case scenarios

For contrasting scenarios in direction coordination: high (green), medium (red), low (blue)

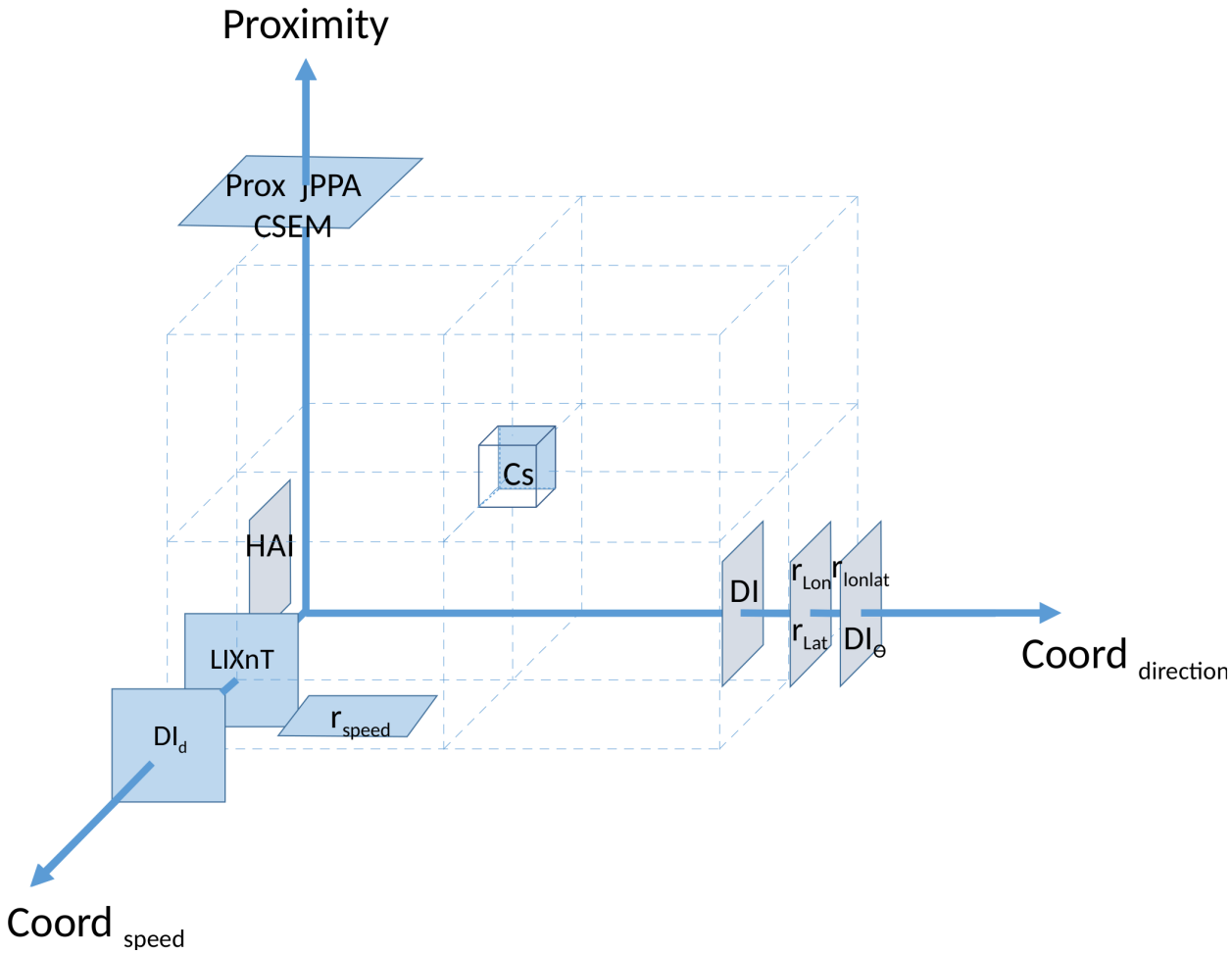


Case scenarios

For contrasting scenarios in speed coordination: same (green), independent (red)



Overall comparison



- Not all metrics are sensitive to each component of joint movement
- Choice of metrics will depend on the component of interest, parameter tuning and assumptions

Extensions

- Obtain **reference points** from metric values to distinguish between high or low joint-movement (manuscript in prep.)
- **Metrics interaction**: dyad characterization through **multivariate** analysis of metrics (manuscript in prep.)
- Use metrics to identify and assess interaction for larger groups

Thanks for your attention