

**Anticipation from Biological Motion:  
the goalkeeper problem**

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When humans observe the actions of others, they can often accurately anticipate the outcome of those actions. This is perhaps best demonstrated on the sports field, for example, in a soccer penalty kick situation. To stop a well-placed penalty kick, the keeper must begin a whole-body movement in the correct direction before the ball has been kicked. The accuracy of the goalkeeper's decision is largely determined by his or her ability to perceive reliable information about kick direction prior to foot-to-ball contact. What properties of the kicker's motion are informative, and when? To investigate this question, I used a motion capture system to record the joint locations of athletes approaching and kicking a ball. Using novel methods, I quantified the reliability of various sources of movement information as predictors of kick direction. Although the reliability of local sources of information (e.g. the angle of the planted foot) were largely consistent with previous accounts, novel computational methods also confirmed the presence of reliable sources of information that were distributed across multiple limb segments, and that reached high levels of reliability as early as 220 ms before foot-to-ball contact. In Experiments 2 and 3, the motion-capture data were used to create stimuli of the kicker's movements prior to foot-to-ball contact, depicted from the keeper's viewpoint. Subjects were asked to anticipate kick direction using a keyboard, and analyses focused on identifying sources of movement information that underlie subjects' judgments of kick direction. The findings indicate that subjects' judgments were based on either distributed information, or some yet-to-be identified source of local information. This study makes contributions to our understanding of how humans are able to perceive complex properties from a biological stimulus. Furthermore, the methods used in these studies have great potential for application within the context of competitive sports recruitment and training.