Human Movement Science 54 (2017) 377–387

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

Influence of gait mode and body orientation on following a walking avatar

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ARTICLE INFO

Keywords:
Complex systems
Interactive sports
Shadowing
Mirroring
Whole-body movement
Joint action

ABSTRACT

Regulating distance with a moving object or person is a key component of human movement and of skillful interpersonal coordination. The current set of experiments aimed to assess the role of gait mode and body orientation on distance regulation using a cyclical locomotor tracking task in which participants followed a virtual leader. In the first experiment, participants moved in the backward-forward direction while the body orientation of the virtual leader was manipulated (i.e., facing towards, or away from the follower), hence imposing an incongruence in gait mode between leader and follower. Distance regulation was spatially less accurate when followers walked backwards. Additionally, a clear trade-off was found between spatial leader-follower accuracy and temporal synchrony. Any perceptual effects were overshadowed by the effect of one's gait mode. In the second experiment we examined lateral following. The results suggested that lateral following was also constrained strongly by perceptual information presented by the leader. Together, these findings demonstrated how locomotor tracking depends on gait mode, but also on the body orientation of whoever is being followed.

1. Introduction

Common daily-life interpersonal coordination such as navigating through a crowd is largely grounded in regulating inter-agent distance (Moussaïd, Helbing, & Theraulaz, 2011). Similarly, in sports it has been proposed that the relative distance between agents (e.g., Okumura et al., 2012) – or even groups of agents (e.g., Frencken, De Poel, Visscher, & Lemmink, 2012) – can be considered a control parameter underlying the organization of sub-groups of players (e.g., Passos et al., 2009). Distance regulation is thus an essential component of inter-agent coordination. Effective distance regulation directly impacts the action possibilities afforded to an agent (Okumura, Kijima, & Yamamoto, 2017). Both when coordinating strictly back- and- forwards (e.g., fencing: Ducourant, Vieilledent, Kerlirzin, & Berthoz, 2005) or when regulating distance laterally (e.g., intercepting an attacker in rugby: Brault, Bideau, Kulpa, & Craig, 2012). In the present study, we examined the distance regulation between a follower and leader in the antero-posterior plane, and in a side-to-side coordination task.

In many typical invasion sports, a defender will be facing an attacker (cf., follower facing a leader). As a defender often aims to regulate its distance to the leader, the defender follows the attacker by adopting a reversed, hence incongruent, gait mode. That is, when an attacker is moving with a forward gait mode, a defender follows by moving with a backward gait mode. Likewise, an attacker moving with a leftward gait mode is followed by moving with a rightward gait mode. Mechanically, backward gait is not

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http://dx.doi.org/10.1016/j.humov.2017.06.005
Received 19 February 2017; Received in revised form 17 June 2017; Accepted 18 June 2017
Available online 07 July 2017

simply a mirrored version of forward gait (e.g., Grasso, Bianchi, & Lacquaniti, 1998; Winter, Pluck, & Yang, 1989). Generally, walking backward is for example performed more slowly than walking forward (e.g., Ducourant et al., 2005). In the example of an attacker and defender, this may provide a competitive advantage for the attacker. Additionally, the incongruent gait modes might imply a perceptual disadvantage. It has been shown that the perception of someone else's movements is more accurate if the movements are similar to one's own movements. For instance, Jacobs and Shiffrar (2005) showed that participants could better identify walking speed of another walker when they were walking themselves as well. Furthermore, there is also an obvious perceptual difference between an approaching and a receding walker (i.e., the allocentric movement direction): Approaching objects provide a larger change in optical size per distance covered compared to receding objects (Lee, 1976).

In a recent study, Meerhoff and De Poel (2014) examined how dyads may switch from in-phase to anti-phase side-to-side coordination. The availability of visual information was manipulated by either having both participants face each other ('face-to-face') or by having one participant facing away from the other ('face-to-back'). The switch between coordination patterns took less time when only one of the participants could see the other. Implicitly, this experimental manipulation also involved a congruence (in the face-to-back situation) or incongruence (face-to-face) in gait mode, which in hindsight may also partly explain the reduction of switch time in the face-to-back situation. In related studies the role of visual information in follow-the-leader task in forward-backward gait was further explored (Meerhoff, 2016; Meerhoff, De Poel, & Button, 2014). Participants had to track a prerecorded receding-approaching stimulus (e.g., a sphere or a walking avatar). Following performance was analyzed both in terms of the temporal synchrony (i.e., did the follower match the timing of its direction changes to the leader) and in terms of spatial alignment (i.e., did the follower maintain the distance with the leader). Results from these studies suggested that when regulating distance, the coordination differed as a function of the gait mode: while walking backwards, following performance decreased compared to walking forwards. In the current study, we report data of two experiments that examined how gait mode and movement direction influenced distance regulation.

1.1. Current experiments

Two experiments were conducted using a virtual leader that was video-displayed on a large screen. Participants followed a prerecorded leader by trying to maintain the initial distance. The first experiment examined antero-posterior following, and the second experiment examined following in the lateral direction. To evaluate the effect of gait mode and movement direction, the body-orientation of the leader was manipulated. As illustrated in Fig. 1, the leader was presented facing either towards the follower (i.e., leader and follower were face-to-face: F2F) or away from the follower (face to back: F2B). In our experiments, the follower required to match movement direction of the leader (cf., in-phase coordination), but by manipulating the body-orientation of the leader the gait mode was either incongruent (F2F) or congruent (F2B). From here onward, we adopt the terminology *'gait mode'* to refer to the egocentric mode of locomotion (i.e., walking back-/forwards, or shuffling left-/rightward) and *'movement direction'* to refer the allocentric displacement with respect to the on-screen projection of the leader (i.e., receding/approaching, or left-/rightward).

2. Experiment 1

Based on Winter et al. (1989) and Grasso et al., 1998 it can be hypothesized that distance regulation becomes less accurate when following with a backwards gait mode (i.e., approaching leader) compared to a forwards gait mode. At the same time, it can be hypothesized that – perceptually – approaching objects are more easily attuned to than receding objects (Lee, 1976). Note that gait mode and movement direction are by definition linked. By manipulating the leader orientation, we can assess the effect of gait mode with congruent and incongruent movements with the leader. The leader's incongruent movements might decrease the follower's coupling strength to the leader (Jacobs & Shiffrar, 2005). Hence we expect that a congruent body orientation (F2B) will improve coordination compared to an incongruent body orientation (F2F). By analyzing the interaction between leader orientation and movement direction, we aim to assess how follower-leader coordination is affected.

2.1. Methods

2.1.1. Participants

Eighteen male participants volunteered for the experiment (aged 21–42 years, mean ± sd = 28 ± 5.4 years,

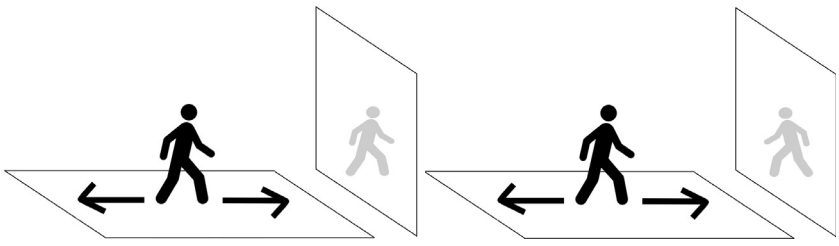

Fig. 1. Schematic overview of the experimental setup: The virtual display of the leader (light grey figure) and the positioning and movement of the follower (dark figure) in orientation F2F (left) and F2B (right).