Gait & Posture 53 (2017) 17–24

Contents lists available at ScienceDirect

Gait & Posture

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

Full length article

Interpersonal interactions for haptic guidance during maximum forward reaching

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ARTICLE INFO

Article history:
Received 27 April 2016
Received in revised form 15 November 2016
Accepted 28 December 2016

Keywords:
Interpersonal touch
Forward reach
Body sway
Social postural coordination

ABSTRACT

Caregiver–patient interactions rely on interpersonal coordination (IPC) involving the haptic and visual modalities. We investigated in healthy individuals spontaneous IPC during joint maximum forward reaching. A 'contact-provider' (CP; n = 2) kept light interpersonal touch (IPT) laterally with the wrist of the extended arm of a forward reaching, blind-folded 'contact-receiver' (CR; n = 22). Due to the stance configuration, CP was intrinsically more stable. CR received haptic feedback during forward reaching in two ways: (1) presence of a light object (OBT) at the fingertips, (2) provision of IPT. CP delivered IPT with or without vision or tracked manually with vision but without IPT. CR's variabilities of Centre-of-Pressure velocity (CoP) and wrist velocity, interpersonal cross-correlations and time lags served as outcome variables. OBT presence increased CR's reaching amplitude and reduced postural variability in the reach end-state. CR's variability was lowest when CP applied IPT without vision. OBT decreased the strength of IPC. Correlation time lags indicated that CP retained a predominantly reactive mode with CR taking the lead. When CP had no vision, presumably preventing an effect of visual dominance, OBT presence made a qualitative difference: with OBT absent, CP was leading CR. This observation might indicate a switch in CR's coordinative strategy by attending mainly to CP's haptic 'anchor'. Our paradigm implies that in clinical settings the sensorimotor states of both interacting partners need to be considered. We speculate that haptic guidance by a caregiver is more effective when IPT resembles the only link between both partners.

1. Introduction

Balance control requires successful integration of self-motion information from multiple sensory modalities [1]. The human postural control system is able to derive self-motion not only from its primary motion detectors but also from actively acquired or passively received light skin contact with the environment [2,3]. Haptic information also stabilizes quiet stance when it originates from a non-weight-bearing contact that possesses motion dynamics of its own, i.e. another human (interpersonal touch; IPT) [4]. Deliberately light IPT is intended to involve small forces only, in order to minimize the mechanical coupling and to maximize the informational exchange [5]. Sway reductions with IPT may emerge from mechanically and informationally coupled adaptive processes and responsiveness in both partners [5].

When joint action partners coordinate their movements they may share information but also face differences in task-relevant knowledge and roles. For example, a blind person receives tactile, visual or verbal cues from the guiding partner. Spontaneous interpersonal postural coordination (IPC) has been demonstrated in diverse joint tasks [6]. For example, implicit observation of a partner in a joint precision task improved manual performance as well as IPC [7]. Verbal communication in a joint problem solving task also influences IPC regardless of whether visual information about the partner was available [8], perhaps mediated by shared speaking patterns [9]. Finally, haptic interactions provide powerful sensory cues for IPC [10]. Coordinative processes supporting goal-directed joint action can result in the emergence of spontaneous leader-follower relationships, for example in a visual, periodic collision avoidance task [11]. In situations such as quiet stance IPT, however, no clear leader-follower relationship has been reported, also not in situations with asymmetrical stance postures with one person intrinsically more stable than the partner [4,12,13].

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http://dx.doi.org/10.1016/j.gaitpost.2016.12.029

A well-established clinical task to assess body balance control is the Functional Reach (FR) [14]. Maximum forward reaching (MFR) challenges the control of body sway as the body's Centre-of-Mass (CoM) approaches the physical limits of stability so that the likelihood of balance loss increases with reaching distance [15]. We assumed that joint action in an asymmetric interpersonal postural context, such as the MFR task with one partner more intrinsically stable, would be more adequate than quiet stance to investigate spontaneously emerging leader-follower relationships. According to the ecological principles of interpersonal affordances [16], we aimed to create dependencies between two individuals by asymmetries in the intrinsic postural stability and in the knowledge of the joint postural state based on the available sensory feedback. We expected that additional haptic feedback, for example as either an additional object or IPT, would increase reach distance but also stabilize body sway in the reaching person (contact-receiver; CR). Further, we anticipated that spontaneous IPC, specifically the leader-follower relationship, is altered by the haptic feedback available to CR as well as by the visual feedback available and the instructions given to the person providing IPT (contact-provider; CP). Although CR would be the main actor performing the MFR, we assumed that CR would become more dependent on CP, when CP was able to perceive the scene.

2. Methods

2.1. Participants

Twenty-two healthy participants (average age = 26.3 yrs, SD = 4.1; 17 females and 5 males; all right-handed for writing) were tested. Participants with any neurological or orthopaedic indications were excluded. Two naïve, healthy young adults provided IPT

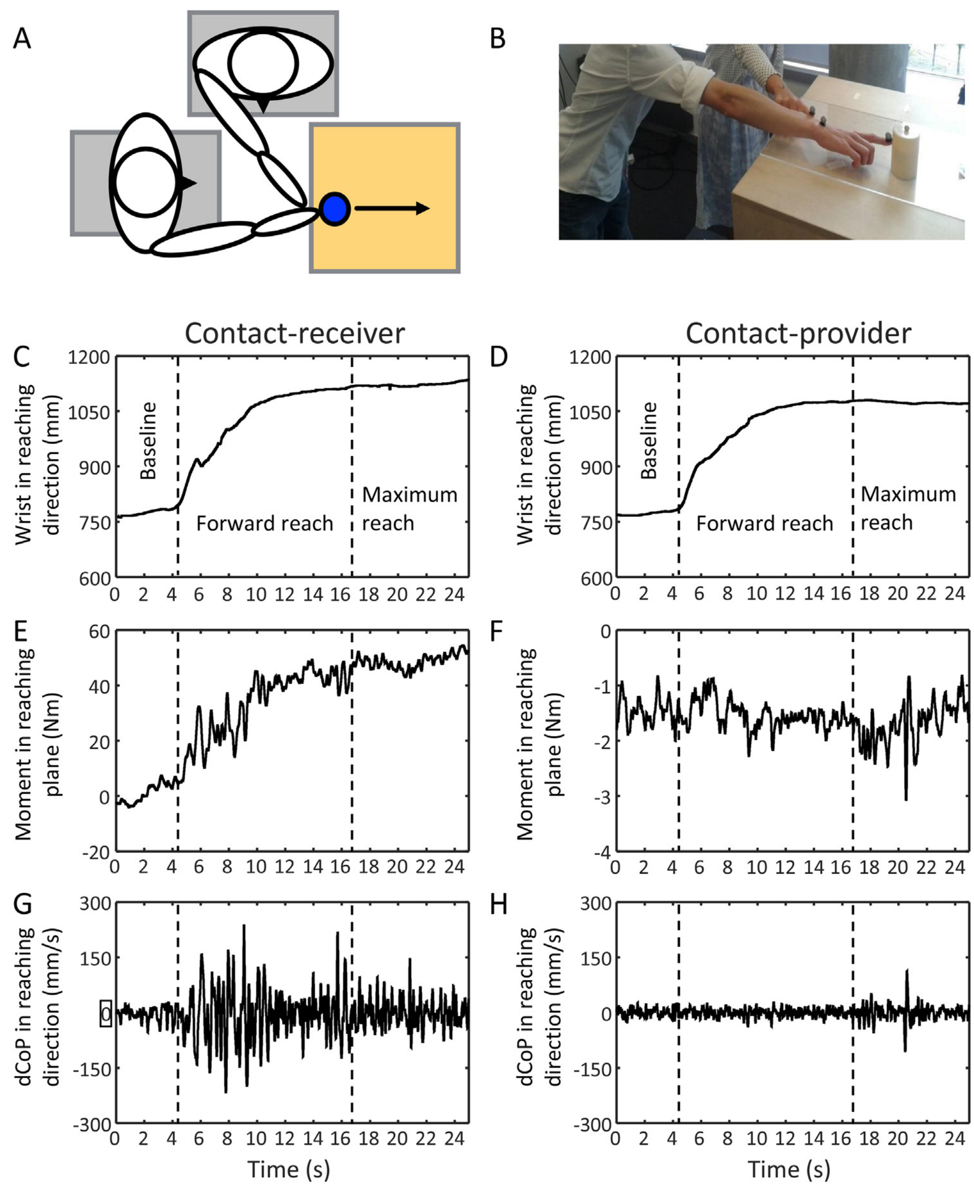

Fig. 1. (A) The stance configuration of the experimental setup at the beginning of a trial. Upon a signal by the experimenter the contact receiver will start the forward reach pushing the object as far out as possible. (B) The contact provider keeping light contact with the receiver's wrist. (C) Position of a receiver's wrist in the reaching direction across single trial. The dashed lines indicate the beginning and end of the forward reach phase. (D) Position of a providers's wrist in the reaching direction across the same trial. (E) Moment in the plane parallel to the reaching direction exerted by the receiver. (F) Corresponding moment exerted by the provider. (G) Receiver's Centre-of-Pressure (CoP) velocity in the reaching direction. (H) Corresponding CoP velocity of the provider.