Cognition 153 (2016) 118–123

Contents lists available at ScienceDirect

Cognition

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

Short Communication

The role of shared visual information for joint action coordination

Cordula Vesper [a,*], Laura Schmitz [a], Lou Safra [b], Natalie Sebanz [a], Günther Knoblich [a]

[a] Department of Cognitive Science, Central European University, Oktober 6 utca 7, 1051 Budapest, Hungary
[b] Ecole Normale Supérieure, PSL Research University, Institut d'Etudes Cognitives, Inserm, U960, Laboratoire de Neurosciences Cognitives (LNC), F-75005 Paris, France

ARTICLE INFO

Article history:
Received 13 August 2015
Revised 1 May 2016
Accepted 2 May 2016

Keywords:
Joint action
Interpersonal coordination
Nonverbal communication
Signaling
Predictability

ABSTRACT

Previous research has identified a number of coordination processes that enable people to perform joint actions. But what determines which coordination processes joint action partners rely on in a given situation? The present study tested whether varying the shared visual information available to co-actors can trigger a shift in coordination processes. Pairs of participants performed a movement task that required them to synchronously arrive at a target from separate starting locations. When participants in a pair received only auditory feedback about the time their partner reached the target they held their movement duration constant to facilitate coordination. When they received additional visual information about each other's movements they switched to a fundamentally different coordination process, exaggerating the curvature of their movements to communicate their arrival time. These findings indicate that the availability of shared perceptual information is a major factor in determining how individuals coordinate their actions to obtain joint outcomes.

1. Introduction

In order to perform joint actions such as throwing and catching a ball, walking hand-in-hand or moving a table together, two or more individuals need to coordinate their actions in space and time while overcoming challenges that arise from not having direct access to each other's sensorimotor processes (Knoblich, Butterfill, & Sebanz, 2011; Knoblich & Jordan, 2003; Wolpert, Doya, & Kawato, 2003). Previous research has identified several different coordination processes that enable joint action partners to overcome these challenges. In some instances, the key to coordination is monitoring each other's actions and predicting their effects on joint outcomes (Keller, 2012; Loehr, Kourtis, Vesper, Sebanz, & Knoblich, 2013; Radke, de Lange, Ullsperger, & de Bruijn, 2011). In other instances, co-actors minimize the time spent in a shared workspace and move away from potential areas of collision, thereby reducing the need for fine-grained coordination (Richardson, Harrison, May, Kallen, & Schmidt, 2011; Vesper, Soutschek, & Schubö, 2009). Further coordination processes include distributing tasks effectively (Brennan, Chen, Dickinson, Neider, & Zelinsky, 2008; Konvalinka, Vuust, Roepstorff, & Frith, 2010), providing communicative signals (Pezzulo, Donnarumma, & Dindo, 2013; Sacheli, Tidoni, Pavone, Aglioti, & Candidi, 2013; Vesper & Richardson, 2014) and keeping one's performance stable across consecutive instances of the same action (Vesper, van der Wel, Knoblich, & Sebanz, 2011).

This multitude of interpersonal coordination processes raises the question of what determines which kind of processes co-actors rely on when faced with a particular joint task. One obvious factor in determining which coordination process is applied is the perceptual information co-actors share. Accordingly, the current study investigated whether augmenting the amount of visual information shared between co-actors could cause a fundamental switch in the way co-actors coordinate their actions. We targeted two coordination processes that were recently reported in the joint action literature.

The first coordination process relates to the use of general heuristic strategies ("coordination smoothers"; Vesper, Butterfill, Knoblich, & Sebanz, 2010). One such coordination strategy is to reduce the temporal variability of one's own behavior. This was shown in a reaction time (RT) study where two people were instructed to respond to visual stimuli as fast and as synchronously as possible (Vesper et al., 2011). RTs were less variable when participants performed the task together than when they performed the task alone. The reduction in intra-individual variability of RT proved to be effective for interpersonal coordination by reducing the asynchronies between co-actors' responses. The underlying coordination strategy of generating consistent timing across multiple action repetitions can be employed across many different joint action contexts such as synchronous and sequential action performance (Vesper et al., 2011), even in the complete absence of information about a co-actor's performance, and it has also been

* Corresponding author.
E-mail address: vesperc@ceu.edu (C. Vesper).

http://dx.doi.org/10.1016/j.cognition.2016.05.002
0010-0277/© 2016 The Authors. Published by Elsevier B.V.

observed in joint actions of non-human primates (Visco-Comandini et al., 2015).

The second coordination process of sensorimotor communication (Pezzulo et al., 2013) assumes that people modulate their actions to transmit task-relevant information. This is particularly useful if one person has privileged access to information relevant for achieving a joint action goal. This person can modulate movement parameters such as direction, velocity, or grip size with the aim of providing specific information to a partner. The partner can identify these modulations as communicative because they deviate from the most efficient way of performing the action as predicted by their own forward models (Wolpert et al., 2003). The exaggerated kinematic information can help to choose between action alternatives (Candidi, Curioni, Donnarumma, Sacheli, & Pezzulo, 2015). It could, however, also support coordination in situations where there is no ambiguity about the joint action target, but uncertainty about another's action timing.

Empirical support for sensorimotor communication has been provided by Sacheli et al. (2013) who instructed two co-actors to simultaneously grasp a bottle-shaped object either at the narrow upper part or at the wide lower part. 'Leaders', who knew where to grasp the object, exaggerated grip size, velocity, and the amplitude of their movements to inform naïve 'followers' about the intended grasp location. Similarly, in a study of synchronous tapping towards a sequence of target locations, leaders informed a naïve task partner about the location of an upcoming target by specifically exaggerating the amplitude of their trajectories relative to the distance between current hand position and subsequent target (Vesper & Richardson, 2014).

In order to test whether people spontaneously select different coordination processes depending on the availability of information about a joint action partner, we developed a task that enabled participants to coordinate either by reducing action variability or by modulating movement parameters in a communicative manner. In contrast to earlier studies on the modulation of movement parameters for communication, relevant task knowledge was not distributed asymmetrically. Therefore, communication was not necessary for successful joint action performance and both coordination processes might therefore be equally effective in supporting joint task performance.

Pairs of participants performed speeded mouse movements to a target presented at the center of two adjacent computer screens (see Fig. 1). They were instructed to arrive at the target as synchronously as possible. The only aspect that differed between the two joint action conditions was whether co-actors could see each other's screens and mouse movements ('visible' condition) or not ('hidden' condition). In line with previous research, we expected that in the 'hidden' condition co-actors would reduce the variability of movement times in order to make their actions more stable (Vesper et al., 2011) and to thus improve coordination.

Of central interest was which coordination process co-actors would rely on in the 'visible' condition. If the availability of shared visual information leads to a preference for communicative modulation of movement they should exaggerate aspects of their movements that provide information supporting coordination (Sacheli et al., 2013; Vesper & Richardson, 2014). Alternatively, co-actors may rely on the strategy of generating consistent timing across multiple action repetitions even if shared perceptual information is available.

2. Method

2.1. Participants

Thirty-two adults (mean age 21.0 years, $SD = 1.61$ years; all right-handed) participated in pairs (six female pairs, two male pairs, eight mixed pairs). They gave prior informed consent and received monetary compensation for their participation. The experiment was conducted in agreement with the Declaration of Helsinki.

2.2. Apparatus and stimuli

Participants were seated next to each other in front of two computer screens. Each screen showed a part of a "space scene" (Fig. 1) with three elements presented on a dark-blue background: (1) A yellow "spaceship" close to the outer margin of each screen (2.5 cm × 1.9 cm; positioned centrally on the vertical axis), indicating the starting position for each trial; (2) a small or large (radius of 2.0 cm or 3.8 cm) "planet" as the target which was a light-blue half circle on the inner margin of each screen at one of three possible vertical locations (20%, 50% or 80% from the upper screen margin); (3) an array of small differently-sized white dots, centered between "spaceship" and "planet", representing an "asteroid belt" (1.9 cm × 9.3 cm; positions at 20%, 35%, 50%, 65% or 80% from upper screen margin) which, in half the trials, created an obstacle between the start and the target location.

The visual stimuli were presented on two 17″-screens (resolution 1280 × 1024 pixel, refresh rate 60 Hz). In the individual blocks and in the 'hidden' condition, an opaque black cardboard

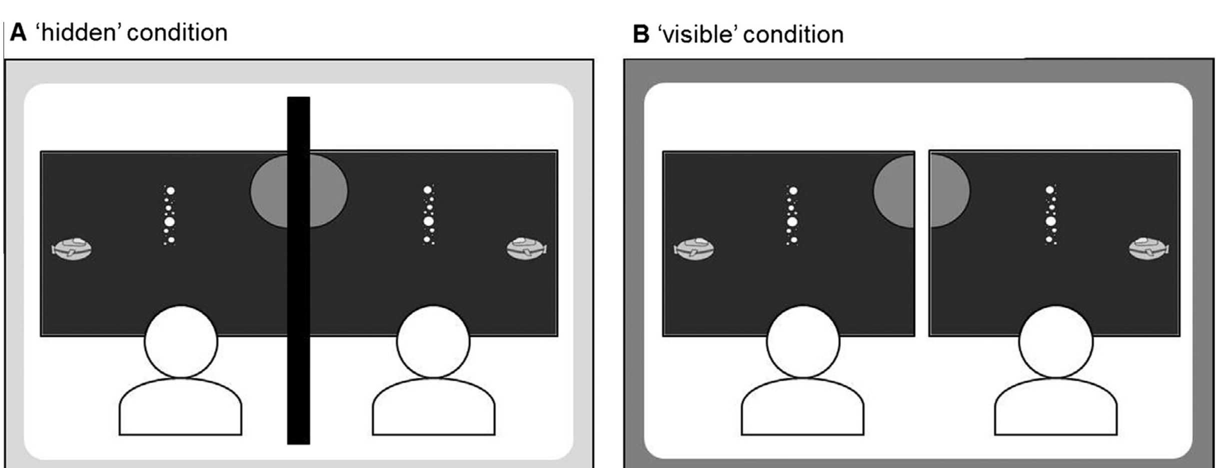

Fig. 1. Schematic depiction of the task setup in the two joint conditions. In the 'hidden' condition, an opaque partition prevented co-actors from seeing each other's screens and movements.