Human Movement Science 31 (2012) 1253–1267

Contents lists available at SciVerse ScienceDirect

Human Movement Science

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

Interpersonal and intrapersonal coordinative modes for joint and single task performance

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ARTICLE INFO

Article history:
Available online 9 March 2012

Psyc INFO Classification:
2840
3040

Keywords:
Interpersonal coordination
Social perception and cognition
Principal component analysis
Cross-recurrence quantification analysis

ABSTRACT

In recent years, research in the field of social interactions has focused on the exploration of the coordinative structures that substantiate joint task performance. The current project explores whether interpersonal coordination during joint task performance gives rise to a joint coordinative structure across individuals, and whether such coordinative structures are affected by task demands. Principal component analysis (PCA) is used to identify relevant interpersonal and intrapersonal coordinative modes for the single and joint performance of a supra-postural task, which varied along its precision and role demands. In addition, cross-recurrence quantification analysis (CRQA) was combined with PCA in order to quantify the degree and stability of interpersonal coordination across intrapersonal coordinative modes. Results indicate that the composition and number of coordinative modes varied for joint compared to single performance, and that interpersonal coordination across the first coordinative mode increased in degree and stability for joint compared to single performance. Overall, these findings indicate that joint coordinative structures are affected by the nature of the task performed and the constraints it places on joint and single performance.

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doi:10.1016/j.humov.2011.12.004

1. Introduction

1.1. Interpersonal coordination

When people interact they often coordinate their movements. Coordination can be an explicit goal of social interactions such as dancing, but even when movement coordination is not the goal of the interaction, such as during conversation, coordination can still occur (Shockley, Santana, & Fowler, 2003). Coordination plays an important role in social interaction. For example, the effectiveness of an interaction can often be directly linked to the degree of interpersonal coordination (Richardson, Marsh, & Schmidt, 2005). Accordingly, a great deal of research has focused on discovering the principles that govern interpersonal coordination (see review by Marsh, Richardson, Baron, & Schmidt, 2006), as well as on developing empirical and methodological strategies for studying coordination during social interactions (Richardson, Dale, & Shockley, 2008). The present study represents continued efforts to advance theory and methodology in the study of interpersonal coordination.

Studies suggest that interpersonal coordination is governed by the same general laws and principles that govern the coordination of an individual actor's movements (Mitra, Riley, Schmidt, & Turvey, 1998; Schmidt, Bienvenu, Fitzpatrick, & Amazeen, 1998; Schmidt, Carello, & Turvey, 1990). For example, it has been proposed that interpersonal coordination, like intrapersonal coordination, may involve the formation of *coordinative structures* (Black, Riley, & McCord, 2007; Schmidt & Richardson, 2008; Shockley, Richardson, & Dale, 2009). Within the context of interpersonal coordination the notion of coordinative structures is used to refer to the soft-assembly of movements by temporarily coupling degrees of freedom of the motion system into higher-order, functional units. The role of coordinative structures in interpersonal coordination is to simplify movement control and supply robustness and integrity to the movement pattern (Bernstein, 1967; Gelfand & Tsetlin, 1966; Turvey, 1977; Turvey, 1990a; Turvey, 1990b; Turvey, Shaw, & Mace, 1978; Whiting, Vogt, & Vereyken, 1992). *Joint coordinative structures* are hypothesized to involve couplings among movement system degrees of freedom of two (or more) people.

Black et al. (2007) found evidence for the joint coordinative structure hypothesis during interpersonal coordination of rhythmic hand movements. Using the uncontrolled manifold method (Scholz & Schöner, 1999), Black et al. discovered that variability of interpersonal coordination patterns contained the reciprocal, compensatory variation among component degrees of freedom that is the signature of coordinative structures (cf. Kelso, Tuller, Vatikiotis-Bateson, & Fowler, 1984). A fluctuation in the position or velocity of one participant's movement, for example, was countered by a change in the other participant's position or velocity so as to preserve the intended relative phase pattern.

It is important, however, to develop convergent methods for addressing the joint coordinative structure hypothesis, and for expanding the task context within which this hypothesis can be investigated. In this study we employed principal component analysis (PCA) to identify correlations among three-dimensional movement trajectories of multiple segments of actors as they performed a joint task that involved precision pointing by one participant toward a target held by the other participant.

1.2. Measuring coordination using principal component analysis

PCA is a multivariate, non-parametric statistical technique that can reveal hidden structure within a complex data set while simultaneously filtering out noise. In studies of human movement, PCA has been used to reduce the dimensionality of complex data sets by determining the most important factors that contribute to the sources of variation in movement patterns (so-called "coordinative modes"), thereby revealing underlying coordinative structures in the correlated patterns of variation among several joints or body segments (Daffertshofer, Lamoth, Meijer, & Beek, 2004; Forner-Cordero, Levin, Li, & Swinnen, 2005). PCA has been applied to the coordination of lower limbs involved in walking (Ormoneit, Black, Hastie, & Kjellstrom, 2004; Vallery & Buss, 2006) and of hand components for different types of grasping tasks (Todorov & Ghahramani, 2004). Coordination of complex whole-body movements has also been explored using PCA for tasks such as dancing (Hollands, Wing, & Daffertshofer, 2004), wrestling (Mikheev, Mohr, Afanasiev, Landis, & Thut, 2002), swinging (Post, Peper, & Beek,