Running head: Joint Action

Psychological research on joint action: Theory and data

Günther Knoblich1, Stephen Butterfill2, & Natalie Sebanz1

1Centre for Cognition, Donders Institute for Brain, Cognition, & Behaviour, Radboud University Nijmegen, The Netherlands;

2Department of Philosophy, University of Warwick, United Kingdom

Address correspondence to:

Günther Knoblich

Radboud University

Donders Institute for Brain, Cognition, & Behaviour

Centre for Cognition

PO Box 9104

6500 HE Nijmegen

The Netherlands

E-mail: g.knoblich@donders.ru.nl

Abstract

NEXT TASKS:

1. COMPLETE REFERENCE LIST
2. CREATE TABLE WITH PROCESSES

# Introduction

Human life is full of joint actions ranging from a handshake to the joint performance of a symphony (Clark, 1996). As Allport (1924) pointed out, there seems to be a certain Gestalt quality to joint action that might make it difficult or even impossible to reduce joint action to individual behaviour: ‘Two boys, between them, lift and carry a log which neither could move alone. You cannot speak of either boy as carrying half the log […]. Nor can you speak of either boy as half carrying the log […]. The two boys, coordinating their efforts upon the log, perform a joint action and achieve a result which is not divisible between the component members of this elementary group.’ How, then, can the basic processes enabling people to perform actions together be studied through psychological experiments? What are the perceptual, cognitive, and motor processes that enable individuals to coordinate their actions with others, and how can the seemingly irreducible components of joint actions be characterized? This article provides an overview of current theories and experiments in psychology that have substantially enhanced our understanding of joint action.

Generally, joint action can be defined as any form of social interaction whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment (Sebanz, Bekkering, & Knoblich, 2006). Coordinating one’s actions with others to achieve a particular outcome, such as lifting a basket and placing it on a table, seems to require some kind of interlocking of individuals’ behaviour, motor commands, action plans, perceptions, or intentions. Early approaches to joint action originate in philosophers’ interest in the nature of joint intentionality. These approaches specify representational systems that enable the planning of joint actions.

(Bratman?, Butterfill?, Gilbert?, Tuomela?)

STEVE: COULD YOU EXPAND TO SUMMARIZE PHILOSOPHERS’ INTEREST IN THIS (max 150 words) AND ADD (up to 10) REFERENCES?

The philosophical work on joint intentionality has guided research on language use where language is conceived of as a form of joint action (Brennan & Hanna, 2009; Clark, 1996). Focusing on common perceptions, common knowledge, and communicative signals, this approach situates joint planning in particular environments and particular interaction histories. For instance, the analysis of joint actions such as assembling furniture together or playing a piano duet has revealed how speech is used to pre-specify who will do what and to agree on the specifics of the joint performance (Clark, 2005). Studies addressing how people solve spatial coordination problems have demonstrated that humans readily invent new symbol systems to coordinate their actions if conventional communication is not an option (Galantucci, 2009).

The philosophical work on joint intentionality has also inspired groundbreaking research on the phylogenetic and ontogenetic roots of joint action and social understanding (Call, 2009; Carpenter, 2009; Tomasello, 2009). Melis, Hare, and Tomasello (2006) found that chimpanzees understand when they need to elicit the help of a con-specific to retrieve food and select the best collaborators to support their actions. This indicates that humans are not the only species to possess a representational system to support the planning of joint actions. However, it seems that humans are especially prone (‘have a special motivation’, Tomasello et al., 2005) to engage in joint action and to help others to achieve their goals (Brownell, Ramani, & Zervas, 2006). For instance, one-year-old infants help adults to achieve their goals (Warneken & Tomasello, 2007). By three years children understand that joint action implies commitment of the individual partners (Graefenhein, Behne, Carpenter, & Tomasello, 2009).

Research on perception, action, and cognitive control has focused on the nuts and bolts of joint action addressing the perceptual, cognitive, and motor mechanisms of planning and coordination. Ecological psychologists have studied rhythmic joint actions in order to determine whether dynamical principles of intrapersonal coordination scale up to the interpersonal case (Marsh, Richardson, & Schmidt, 2009). This research has shown that in many cases the movement of limbs belonging to different people follows the same mathematical principles as the movement of an individual’s limbs (e.g., Schmidt, Carello, & Turvey, 1990). Cognitive psychologists have studied how co-actors represent each other’s tasks and how the ability to predict each other’s actions supports coordination in real time (Sebanz, Bekkering, & Knoblich, 2006). The results of this research suggest that specific perceptual, motor, and cognitive processes support joint action (Knoblich & Sebanz, 2008; Semin & Cacioppo, 2007) and that the needs of joint action shape individual perception, action, and cognition (Knoblich & Sebanz, 2006).

The present article provides a review of recent joint action research with a focus on the nuts and bolts of joint action. In order to place this research in a wider Cognitive Science context we begin by outlining a model that encompasses the main processes supporting interpersonal coordination during joint action.

# The iceberg model of joint action (1500 words, 6 pages)

The iceberg model of joint action (Figure 1) illustrates two types of coordination that can occur during joint action, planned coordination and emergent coordination. Planned coordination (PC) is apparent to some degree to those engaged in or observing joint action. Just as only the tips of an iceberg are visible to an observer, joint action appears as the coordinated behaviour of two agents who are separate entities with separate mental machineries and who need to exchange meaningful signals in order to coordinate their plans. The assumption that is of key interest for the present purpose is that coordination between agents requires mental representations that are directed at coordinating planning with each other ~~and include aspects of other agents’ plans (Vesper, Butterfill, Knoblich, & Sebanz, in press)~~. Thus this part of the picture highlights the role of shared intentions and common knowledge in joint action but it also includes other, less conceptually sophisticated representations for coordinating action.

In emergent coordination (EC), coordinated behaviour occurs due to perception-action couplings that make multiple individuals act in similar ways; it is independent of any joint plans or common knowledge (which may be altogether absent) and does not require mental representations directed at coordinating with another’s plans. Just as the base of an iceberg is invisible to an observer, the workings of perception-action couplings remain invisible because they do not directly involve the agents’ intentions or knowledge. However, agents may process perceptual and motor cues in the same way as each other. Thus coordination between agents may emerge without exchange of any conventional coordination signals. Two separate agents may start to act as a single coordinated entity (Marsh et al., 2009; Spivey, 2007) because common processes in the individual agents are driven by the same cues and motor routines.

## Emergent coordination (500 words)

Emergent coordination can occur spontaneously between individuals who have no plan to perform actions together as well as during planned joint actions. For instance, pedestrians often fall into the same walking patterns (Van Ulzen et al., 2008) and people engaged in conversation synchronize their body sway (Shockley, Santana, & Fowler, 2003) and mimic each other’s mannerisms (Chartrand & Bargh, 1999). In all of these instances of emergent coordination similar behaviours occur spontaneously in two agents. Because these similarities don’t seem instrumental for either individual goals or joint goals, emergent coordination has sometimes been portrayed as a single process (Semin & Cacioppo, 2007). However, if (as we believe) emergent coordination is a key facilitator of joint action then it is essential to distinguish different processes that give rise to emergent coordination according to different dimensions that drive the coordination. We will distinguish between five such processes, 1) entrainment, 2) common affordances, 3) common salience, 4) perception action matching, and 5) action simulation.

### *Entrainment*

Entrainment is perhaps the most widely studied social motor coordination process (Schmidt, Fitzpatrick, Caron, & Mergeche, in press). For instance, two people in rocking chairs involuntarily synchronize their rocking frequencies (Richardson, Marsh, Eisenhower, Goodman, & Schmidt, 2007), and audiences in theatres tend to clap in unison (Neda, Ravasz, Brechet, Vicsek, & Barabasi, 2000). Entrainment is a process that leads to temporal coordination of two actors’ behaviour, in particular, synchronization, even in the absence of a direct mechanical coupling. In dynamical systems research interpersonal entrainment is often considered as a particular instance of the coupling of rhythmic oscillators (Schmidt & Richardson, 2008) that is frequently observed in mechanical as well as biological systems. However, there are now first indications that social coordination constitutes a specific process that can be identified through particular markers of brain activity (Tognoli, Lagarde, DeGuzman, & Kelso, 2007).

### *Common Affordances*

Whereas entrainment occurs in the direct interaction between agents, common object affordances provide the basis for a further dynamical process of emergent coordination. Object affordances (Gibson, 1977) previously discussed as the ‘funktionale Toenung’ of objects (von Uexkuell, 1920) specify the action opportunities that an object provides for an agent with a particular action repertoire. For instance a chair ‘invites’ sitting down on it. When two agents have similar action repertoires and perceive the same object, they are likely to engage in similar actions because the object affords the same action for both of them. This can lead to emergent coordination when agents perceive the same objects at the same time. Examples for objects with a common affordance that may induce emergent coordination include the arrival of a bus, an apple falling from a tree, and a bench in the park.

### *Common Salience*

Coordination can also be facilitated by the salience of certain ways of coordinating, providing of course that relevant patterns of salience are common to all agents. A famous example is Schelling’s (1960) hypothetical coordination task of meeting someone in New York on the next day without being able to communicate with that person. Despite the many possible number of places, most people chose Grand Central Station. In general, common salience may enable multiple agents to fix on a single ways of coordinating without any agreement to do so.

### *Perception-action matching: Common action representations*

A third process that can lead to emergent coordination is the matching of observed actions onto the observer’s own action repertoire. Such a matching can lead to mimicry of observed actions because perceiving a particular action activates corresponding representations that also guide the actions of the observer. Common representations in perception and action have been postulated in extensions (Hommel, Muesseler, Aschersleben, & Prinz, 2001; Jeannerod, 1999; Prinz, 1997) of ideomotor theories of voluntary action control (James, 1890) and have received neurophysiological support from single-cell studies in monkeys and brain imaging studies in humans (Rizolatti & Sinigalia, 2010). In monkeys and humans the matching is based on the similarity in actor-object relations. For instance, seeing someone grasp a grape activates grasping actions directed at small, round objects. In humans, the matching can also be based on similarity in intransitive movements that are not directed at objects. For instance, observing someone dancing will activate corresponding action representations if one knows how to dance (Calvo-Merino, Cross). The perception action match can lead to emergent coordination because it induces the same action tendencies in different agents who observe each other’s actions (Knoblich & Sebanz, 2008).

### *Action simulation: Common predictive models*

The fourth process of emergent coordination is closely related to the perception action matching described above. Once a match between observed and performed actions is established it enables the observer to apply predictive models in his or her motor system to accurately predict the timing and outcomes of observed actions. This processes is often referred to as action simulation (Sebanz & Knoblich, 2009) because it uses internal models guiding an agent’s own actions to predict other agents’ actions in real time (Wolpert, Doya, & Kawato, 2003). To illustrate, a basketball player observing a shot will be able to accurately predict whether the shot will be a hit or a miss (Aglioti, Cesari, & Romani, & Urgesi, 2008). Action simulation can lead to emergent coordination because it induces the same expectations about the unfolding of actions in different actors and thus induces similar action tendencies for future actions (Knoblich & Sebanz, 2008).

## Planned coordination (500 words):

Minimally joint action requires only that each agent have a plan specifying the joint action outcome (j) and her own part in bringing it about (me). The other’s part can remain unspecified as captured by the formula ‘j = me + x’ for the minimal case (Vesper, Butterfill, Knoblich, & Sebanz, in press). Starting with minimal representational requirements (Clark, 1997) allows one to address a wide range of joint actions (Tollefsen, 2005) in which the extent to which other agents’ tasks, perceptions, and cognition are taken into account during planning of joint actions varies greatly. By contrast, philosophical approaches to understanding joint action have generally assumed that joint actions involve detailed representations of other agents or their plans (e.g. Bratman, 1993; Roth, 2004; Tomasello, Carpenter, Call, Behne, & Moll, 2005); given our interest in the nuts and bolts of joint action this is unhelpfully restrictive.

In the minimal case, where the other’s part is not represented, coordination of plans relies entirely on the processes of emergent coordination described above. These mechanisms alone are not sufficient to enable joint actions where two agents perform different tasks in pursuit of a potentially novel goal that neither of the agents could perform alone. In order to perform joint actions, such as playing a piano duet or lifting a heavy log, planned coordination is required. In planned coordination mental representations are partly responsible for coordination of the agents’ actions plans. The agents plan their own actions in relation to joint action outcomes or in relation to others’ actions, whereas planning is absent or confined to the agent’s own actions in emergent coordination. We distinguish three (of perhaps many more) processes for planned coordination, 1) Joint task representations, 2) Joint perceptions and 3) common knowledge.

### Joint task representations

In minimal cases of joint action, actors represent an outcome that they are not going to achieve alone and the task they need to perform themselves. Very often, though, joint action involves representations of the other agents who are actually and potentially involved. For instance, a chimpanzee who can only get food from a tray with the help of a con-specific may select one among several potential helpers according to how useful each is likely to be (Melis, Hare, & Tomasello, 2006). This chimpanzee needs to represent the goal to obtain food and their own task of pulling a rope, but need not have detailed representations of the con-specific’s actions. Often, however, representations of others’ tasks are more detailed, specifying the actions others are going to perform. This is demonstrated by children’s (Carpenter, 2009) and adults’ proneness to represent specifics of others’ actions and tasks (Sebanz, Knoblich, & Prinz, 2005).

Joint task representations provide control structures that allow agents to flexibly engage in planned coordination. Joint task representations do not only specify in advance the individual parts each agent (me and you in the simplest case) is going to perform but they also govern monitoring and prediction processes that enable interpersonal coordination in real time (Knoblich & Jordan, 2002; Pacherie & Dokic, 2006). For instance, two attackers in soccer specialized on serves and scores, respectively, will not only represent each other’s tasks in the team but will also monitor and predict each other’s running paths in the light of the individual tasks.

### Joint perceptions

Planned coordination can be improved by including another’s perceptions into one’s representation of the other’s task. This can consist in taking the other’s perspective in situations where co-actors’ perspectives on a jointly perceived environment differ such as when two actors sit face to face looking at objects to be assembled. Or it can consist in inferring what a co-actor can or cannot perceive in situations where perceptual access to objects in the environment differs between co-actors (Brennan & Hannah, 2009; Keysar et al., 2009). Although it is debated how prone agents are to co-representing each other’s perceptions, there is some evidence that at least some aspects of another’s perspective are computed even doing so hinders one’s own performance (Samson et al, in press). C. Co-representated perceptions might be highly useful for planned coordination in helping to establish perceptual common ground between actors (Clark, 1996), in enabling one to adapt one’s own task, and in facilitating monitoring of the other’s task.

### Common knowledge

Planned coordination can also be improved by retrieving knowledge from long-term memory. Knowledge can benefit planned coordination as long as all agents involved in a joint action assume that it is shared; such knowledge can include common ground (Clark, 1996) as well as knowledge of precedents and conventions. For example, consider again Schelling’s game in which two people have to meet in New York without communication but now suppose that it is common knowledge among participants that one of them is arriving at JFK airport. As this example suggests, common knowledge can be used to adapt one’s own plans to what the other is expected to do and to generate expectations about the other’s part in the joint action.

# Evidence (7000 words, 28 pages)

## Emergent coordination (1500 words, 6 pages)

### *Entrainment (750 words)*

Even when people do not intend to coordinate or intend to keep their own rhythm, they tend to fall into synchrony. This has been demonstrated for manual movements like clapping, tapping, drumming, and for whole body movements like rocking and walking.

Schmidt, 1997

SWINGING HAND-HELD PENDULUMS Schmidt & O’Brian 1997: Pairs of participant were instructed to swing a pendulum at a particular rhythm. When looking at each other, their swinging became synchronized.

CLAPPING Néda, Ravasz, Brechet, Vicsek, & Barabási, 2000: Audiences fall into synchrony (intermixed with periods of louder less synchronized clapping)

TAPPING Oullier, De Guzman, Jantzen, Lagarde & Kelso, 2008: people unintentionally synchronize tapping movements

Tognoli, Lagarde, DeGuzman & Kelso, 2007: used same paradigm to investigate neural markers of entrainment

LIMB MOVEMENTS (FORARMS): Issartel, Marin, & Cadopi, 2007

DRUMMING: Kirschner and Tomasello (2009) found that even 2.5 years old children adjusted their drumming tempo to a beat outside the range of their spontaneous motor tempo when drumming in the presence of an interaction partner

ROCKING Richardson, Marsh, Isenhower, Goodman & Schmidt, 2007: people in rocking chairs have a tendency to synchronize their rocking, even when this goes against the chair’s eigenfrequency

WALKING Van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2008: people walking next to each other fall into synchrony (to a limited extent though), see also Zivotofsky & Hausdorff, 2007

### *Affordances (100-200 words)*

No studies? Examples? Observational studies?

Although object affordances have been studied extensively in research on individual perception (Jones 2003), we are not aware of any psychological research looking at the role of affordances in coordinating behavior between different individuals. Note that some researchers have started to explore how the presence of another person provides affordances for acting together ( Richardson et al. 2007, 2008). This is different from the mechanism we consider here, because in our scenario actors do not perceive actor–object relations.

### *Perception action matching (200-300 words)*

Mimicry studies with two people and without conversation?

Are there examples where people mimic each other in a way that implies variable timing.

### *Action simulation (200-300 words)*

Potential alternative mechanism for stimulus driven entrainment especially when flexible and context-sensitive timing is required. What are the relevant studies?

Flanagan, predictive gaze?

## Emergent coordination during joint action (1250 words, 5 pages)

### *Entrainment (500 words)*

Fowler, C. A. Richardson, M. J., Marsh, K. L., & Shockley, K. D. (2008). Language use, coordination, and the emergence of cooperative action. In A. Fuchs & V. Jirsa (Eds.) Coordination: Neural, Behavioral and Social Dynamics. Springer.

#### Action.

Entrainment occurs during conversation (and may support it functionally). This has been shown for synchronization of postural sway and for synchronization of eye movements. The eye movement work suggests that synchronization aids understanding.

PENDULUM

Richardson, Marsh & Schmidt, 2005

SWAYING

Shockley, Santana & Fowler, 2003: Body sway in individuals talking to each other is synchronized even when they cannot see each other

Shockley, Baker, Richardson & Fowler, 2007: this is modulated by properties of speech (dyadic speaking rate and similarity in stress patterns of words).

Stoffregen, Giveans, Villard, Yank & Shockley, 2009 point out that “it is unlikely that conversational dynamics are the sole factor influencing such coordination because when they evaluated the postural coordination of participants who uttered the same words in the same order, but did the task at a different time (i.e.. virtual pairings), they found no influence of speech similarity”.

Note: Stoffregen et al. found postural synchronization only on rigid surface (not clear what this means)

FITTS LAW:

Mottet et al., 2001

MUSIC

Clayton et al., 2004 and Congado studies

#### Perception.

EYE MOVEMENTS

Richardson & Dale 2005: listeners make similar eye movements as speakers even when they cannot see the speaker; comprehension better for more closely coupled listeners

Richardson, Dale, & Kirkham 2007: same finding but in real time dialogue (speaker and listener cannot see each other)

Richardson, Dale, & Kirkham 2007: common knowledge increases entrainment

Richardson, Dale, Tomlinson, & Clark 2008 &

Richardson, Dale, & Tomlinson 2009: belief about what other can see changes coordination of eye gaze

### *Perception action matching (500 words)*

Chartrand, van Baaren (clearly separate entrainment and mimicry!!!)

### *Action simulation (100 words)*

??? Alternative proposal for stimulus driven entrainment

## Side effects of emergent coordination (750 words, 3 pages)

### *Entrainment*

#### Action. (250 words)

affiliation LIKING

Miles, Nind, & Macrae, 2009: Perception of interpersonal connectedness depends on synchronization (observers report highest level of rapport when they observe synchronized interaction (0, 180 deg), least for most de-synchronized interaction (90, 270deg)

Hove & Risen 2009: synchronized tapping increases liking (affiliation ratings)

(note: earlier work has not provided conclusive evidence and tends to be correlational rather than showing a causal link)

Wiltermuth & Heath, 2009: acting in synchrony with others increases willingness to cooperate by increasing group cohesion

Valdesolo et al., 2009, Enhanced perception in joint action through entrainment

#### Perception. (250 words)

improved understanding and memory (Daniel Richardson)

IMPROVED PERFORMANCE

Richardson & Dale, 2005: degree of recurrence between individual speaker-listener pairs reliably predicted how many of the comprehension questions the listener answered correctly. A second experiment provides evidence that gaze coordination and comprehension are causally connected. Participants responded to comprehension questions more readily when pictures were flashed in time with the speakers’ fixations (making the listener more similar to the speaker in terms of gaze) compared to a randomized version.

### *Perception action match (250 words)*

Van Baaren & Chartrand and others

### *Action simulation*

???

## Planned coordination (1250 words, 5 pages)

### *Joint task representations*

#### Basic processes. (500 words)

Co-representation as the main evidence that x is not minimal in humans performing tasks together.

Task co-representation in turn taking

Atmaca, Sebanz, Prinz, & Knoblich, 2008. SNARC

Milanese, Iani, & Rubichi (in press)

Ramnani & Miall, 2004

Sebanz et al., (2003, 2006a, 2006b, 2007)

Tsai, Kuo, Jing, Hung, & Tzeng (2006).

Task co-representation in synchronized action

Sebanz et al., (2005)

#### Interpersonal factors (300 words).

Hommel & Colzato -> me + x may depend on liking, mood, mentalizing skills, feedback about the other’s actions.

Becchio, Satori, Bulgheroni, & Castiello (2007). Cooperation vs. competition between agents.

Becchio et al. Consciousness and Cognition

Georgiu, Becchio et al., 2006: Cooperation and competition

Sartori et al. 2009

De Bruin, Miedl, & Bekkering (???). Competition and joint Simon

Hommel, Colzato, & van den Wildenberg (2009)

Ruys & Aarts (in press).

Tsai, Kuo, Hung, & Tzeng (2008)

Welsh (2009)

### *Joint perceptions (300 words)*

Keysar/ Brennan

Brennan, Chen, Dickinson, Neider, & Zelinsky, 2008. Joint planning in a visual search task.

Frischen, Loach, & Tipper (2009). Reference frames in turn taking

Welsh et al. (2005)

Welsh et al. (2007)

### *Joint heuristics and joint knowledge (remove???)*

Speeding etc.

Galantucci

## Synergies between planned and emergent coordination (2000 words, 8 pages)

### *Planning and Entrainment (1000 words)*

Studies on entrainment where people are instructed to coordinate in different ways suggest that the same properties that apply to a system comprised of one individual apply to a system comprised of two (or more) people. Thus, the same lawful regularities may hold within and across actors. This is suggested by studies investigating the stability of particular movement patterns within and across people. When moving their fingers or legs, people adopt particular movement patterns (e.g., symmetric vs. parallel mode). This also applies to dyads. It is unclear whether this also holds when people do not intend to produce a particular pattern (preliminary evidence comes from a study that investigated whether two people who are connected to each other walk like a quadruped).

LEG SWINGING Schmidt, Carello, & Turvey, 1990: in-phase movements were more stable than anti-phase movements within and between people

PENDULUM: Schmidt & Turvey 1994 used hand-held pendulums where length and mass was manipulated; Schmidt, Bienvenu, Fitzpatrick & Amazeen, 1998 manipulated coordination mode, frequency of oscillation, difference in eigenfrequency

WALKING

Van Ulzen et al., 2008

QUADRUPEDAL WALKING Harrison & Richardson, in press: naive walkers were visually or mechanically coupled to see whether they would synchronize their leg movements and produced gaits associated with quadrupedal locomotion; “stable multi-legged coordination patterns can emerge without direct neural-muscular coupling between all of the participating limbs”

Oullier, De Guzman, Jantzen, Lagarde & Kelso, 2008: people synchronize tapping movements, and continue with eyes closed (memory effect) (violation of two-as-one system principle)

Learning of entrainment by couple interacting over longer time/memory?

suggested by Stoffregen, Giveans, Villard, Yank & Shockley, 2009: postural synchronization only on rigid surface-certain aspects of the findings raise question whether there is learning, and whether synchronization has functional role

Bosga et al. EBR 2007 (Coordination): Jointly moving a rocking board, task with different components solved in a dynamical fashion -> Physical coupling between people

MUSIC: Goebl & Palmer (2009). Synchronization between pianists and use of ostensive cues

DRUMMING: Kirschner and Tomasello (2009) found that even 2.5 years old children adjusted their drumming tempo to a beat outside the range of their spontaneous motor tempo when drumming in the presence of an interaction partner -> one person could plan to improve the other’s performance or is this not planned, at all?

How does the following study fit in? Konvalinka, Vuust, Roepstorff, & Frith, in press: no leader-follower pattern; rather, constant prediction and adaptation to each other (“hyper-following”)

### *Planning and Affordance (200 words)*

Richardson plank lifiting

### *Planning and perception action matching (200 words)*

Newman-Norlund, van Schie, van Zuijlen, & Bekkering (2007)

Schuch & Tipper (2007)

### *Planning and action simulation (500 words)*

separate monitoring and prediction of action outcomes (Keller, Knoblich, Repp, Knoblich & Jordan, 2003; Vesper et al., in prep.). Possibility that only joint and not individual action outcomes are monitored.

Bosga et al., 2007, Motor Control: Joint lifting task (could also be in entrainment section)

Knoblich & Jordan (2003); Keller, Knoblich, & Repp (2007); Vesper/Schuboe??

# Discussion (1500 words, 6 pages)

Similarity of joint action planning/coordination processes to what is needed in ‘executive’ functions when a person performs multiple tasks. Can couples serve as a model for executive functions? Is multitasking internalized joint action?

## Unit of analysis: 100 words

Hutchins, 1995, Cockpit

-> point back to Allport citation in the beginning.

## Commitment: 200 words

Gilbert 1989, 1990

Developmental: Graefenhain, Behne, Carpenter, & Tomasello (2009).

## Competition/Dilemma vs joint action: 100 words

Game theory and competitive situations (Braun, Ortega, Wolpert 2009)

## Robotics

### *Robotics, Neuromodels: Erlhagen, who else? 100 words*

### *Robotics, Joint work spaces, Breazeal 100 words*

### *Robotics, Experience: De Jaegher, DiPaolo, & Gallagher (in press?) 100 words*

Contextual, enabling, constitutive role of social interaction in social cognition

### *Robotics, Haptic coordination 500 words*

Groten et al.,

Feth et al., Proceedings,

Auvray et al.,

Reed et al.

Ruddle et al.

Salinas & Zhai

Streubner

End with Titanic?

# References

Calvo-Merino, B., Glaser, D., Grèzes, J., Passingham, R., & Haggard, P. (2005). Action

observation and acquired motor skills: An fMRI study with expert dancers. *Cerebral*

*Cortex, 15,* 1243-1249.

Schmidt, R.C., Fitzpatrick, P., Caron, R., & Mergeche, J. (in press). Understanding social motor coordination. Human Movement Science.

Schmidt, R. C., & Richardson, M. J. (2008). Dynamics of Interpersonal Coordination. In A. Fuchs & V. Jirsa (Eds.) Coordination: Neural, Behavioral and Social Dynamics. Springer.

# Acknowledgements

We thank Brian Ross for …

# Figure captions

Figure 1: The iceberg model of joint action. Perception-action couplings, which include entrainment, perception action matching, and action simulation, ‘fuse’ different agents. These couplings are established through temporal cues, object affordances, and kinematic cues. The tight link between agents created by perception action couplings reduces the need for coordination signals. However, perception action couplings are not sufficient where joint action requires that agents perform different actions at different times. In such cases agents need to differentiate between parts of the joint action they can achieve alone and parts they cannot achieve. The need to represent in greater detail differences between one’s own part in a joint action and another’s part in the joint action creates a widening gap in the sense that coordination is less and less a by-product of perception action couplings. Instead, coordination increasingly depends on additional signals that relate each other’s parts in the joint action.

Figure 1.