Running head: Joint Action

Psychological research on joint action: Theory and data

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Abstract

NEXT TASKS:

1. COMPLETE REFERENCE LIST
2. CREATE TABLE WITH PROCESSES

# Introduction (500 words, 2 pages)

Human life is full of joint actions ranging from a handshake to the 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, a joint action is a 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 potentially novel outcome, such as lifting a particular basket and placing it on a certain 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.

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

Philosophers generally agree that joint actions are actions done with shared intentions: what distinguishes joint from individual actions is that the joint ones involve a shared intention, and shared intentions are essential for understanding coordination in joint action. This conceals deep disagreement on what shared intentions are. Some hold that shared intentions differ from individual intentions with respect to the attitude involved (Kutz, 2000; Searle, 1990 [2002]). Others have explored the notion that shared intentions differ with respect to their subjects, which are plural (Gilbert, 1992), or that they differ from individual intentions in the way they arise, namely through team reasoning (Gold & Sugden, 2007), or that shared intentions involve distinctive obligations or commitments to others (Gilbert, 1992; Roth, 2004). Opposing all such views, Michael Bratman (1992, 2009) argues that shared intentions can be realised by multiple ordinary individual intentions and other attitudes whose contents interlock in a distinctive way. Perhaps some of the disagreement among philosophers arises from the fact that joint action is a heterogeneous notion.

Bratman, M. (1992). Shared Cooperative Activity. *The Philosophical Review, 101*(2), 327-341.

Bratman, M. (2009). Modest Sociality and the Distinctiveness of Intention. *Philosophical Studies, 144*(1), 149-165.

Gilbert, M. (1992). *On Social Facts*. Princeton, NJ: Princeton University Press.

Gold, N., & Sugden, R. (2007). Collective Intentions and Team Agency. *Journal of Philosophy, 104*(3), 109-137.

Kutz, C. (2000). Acting Together. *Philosophy and Phenomenological Research, 61*(1), 1-31.

Roth, A. S. (2004). Shared Agency and Contralateral Commitments. *The Philosophical Review, 113*(3), 359-410.

Searle, J. R. (1990 [2002]). Collective Intentions and Actions. In *Consciousness and Language* (pp. 90-105). Cambridge: Cambridge University Press.

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 conspecific 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 (Graefenhain, 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.

STEVE: FEEL FREE TO CHANGE THE BLACK PARTS. PLEASE DO NOT CHANGE THE RED PARTS. COMMENTS IN BLACK OR BLUE VERY WELCOME.

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

The iceberg model of joint action in Figure 1 illustrates the fact that agents can achieve coordination in two different ways. Just as only the tips of an iceberg are visible to an observer, joint action to an observer appears as a 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. This part of the picture highlights the role of joint intentionality and joint planning in joint action. The assumption that is of key interest for the present purpose is that coordination between agents requires mental representations that are directed at future events (plans) and include aspects of other agents’ plans. We will refer to this as ‘planned coordination’ (PC).

Coordinated behaviour may also emerge in the absence of joint plans due to perception action couplings that make multiple individuals act in similar ways. Just as the base of an iceberg is invisible to an observer, the workings of perception action couplings remain invisible because they do not involve coordination signals that would reveal any underlying joint intentions. However, agents may process perceived and/or internally generated perceptual and motor cues in the same way. Thus coordination between agents may emerge without any coordination signals. Two separate agents may start to act as a single coordinated entity (Marsh) because common processes in the individual agents are driven by the same cues and motor routines. We will refer to this as ‘emergent coordination’ (EC).

EC -> me is not in relation to others’ actions, me is me

PC -> me is in relation to others’ actions (other events in the minimal case), me is part of something larger

EXPAND (UP TO 250 WORDS)

## Emergent coordination (500 words)

Emergent coordination can occur spontaneously between individuals that have no plan to perform actions together as well as during planned joint actions that do not require entrainment.

Schmidt, R.C., Fitzpatrick, P., Caron, R., & Mergeche, J. (in press). Understanding social motor coordination. Human Movement Science. (Reviews synchronization work and reports new data on martial arts, hand clapping games, and joke telling to make the point that synchronization occurs in complex, natural interactions and not just in artificial lab situations)

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

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.

Marsh, K. L., Johnston, L., Richardson, M. J., & Schmidt, R. C. (2009). Toward a radically embodied, embedded social psychology. European Journal of Social Psychology, 39, 7, 1217-1225.

### *Entrainment: Common rhythms*

From within person coordination to between person coordination

Process: entrainment

Entrainment can have cognitive side effects such as understanding

### *Affordances: Common pull towards objects*

Process: similar action tendencies activated by objects

Knoblich & Sebanz, Philosophical Transactions, 2008:

Whereas entrainment arises in a direct interaction between two (or more) organisms perceiving each other, the ecological framework seems to leave room for another mechanism of coordinated behavior that is mediated by object affordances (cf . ‘funktionale Toenung’, von Uexkuell 1920; Gibson 1977). When two organisms have a similar action repertoire and perceive the same object, they are likely to exhibit similar behaviors because the object ‘affords’ (invites) the same actions for them.

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: Common action representations*

Processes:

1. Same or similar action tendencies activated by observed actor-object relation (perception action match, transitive)
2. Same or similar action tendencies activated by observed actions (perception action match, intransitive)

Knoblich & Jordan, 2002

Pacherie & Dokic, 2006

### *Action simulation: Common predictive models*

Process: predictive models in the motor system are applied to observed actions

Material for emergent

We propose several processes that lead to two different kinds of sharing (see Figure x). One set of processes leads to multiple individuals acting in similar ways or having similar mental representations of actions. The fact that individuals act in a similar way or have similar action representations can be regarded as a sharing of actor-environment relations and a sharing of action plans, respectively. Importantly, however, this kind of sharing that does not involve an awareness of how one’s own actions and others’ actions are related. Nor does it involve awareness on the individuals’ part that actor-environment relations or action plans happen to be shared. Thus, one could say that sharing is simply in the eye of the observer. We refer to this as \*similarity-based sharing/emergent sharing/ implicit sharing/non-relational sharing/parallel sharing??

## Planned coordination (500 words):

### Joint task representations

me + x! (Vesper et al., in press)

Tollefsen, 2005 for a developmental version

Table that gives overview over the different processes involved in emergent coordination and planned coordination.

Representing the goal of one’s own action is not sufficient. Minimally needed: representation of missing part: me + x.

X can be expanded to represent more detailed and complex content such as exactly what is missing in terms of natural forces (gravity, wind, etc) and in terms of actions/actors.

Co-representation as the main evidence that x is not minimal in humans performing tasks together. Hommel & Colzato -> me + x may depend on liking, mood, mentalizing skills, feedback about the other’s actions.

Processes drawing on these representations enhance planning to be more flexible:

Role distribution??? Fixed in animals. Which process could create flexibility using the me + x representation? Possible start: Assigning different roles to me and x. Decoupling tasks and actors (x needs to be specified to a degree that allows me to do x part, at the same time me would become x).

1. 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.
2. separate monitoring and prediction of perception that are not individual or joint action outcomes, e.g., different perspectives (always individual!). THINK ABOUT THE ASSYMMETRY BETWEEN THIS AND ABOVE. More ambiguity for perception of action outcomes than for perception of objects and events that are not individual/joint action outcomes. Samson/Anne etc. to demonstrate that other’s perception is calculated.
3. separate monitoring and predictions of mental states (always individual). Keysar/Brennan diskutieren.
4. Start with distinction between advance preparation and online planning. Strategies preset perception-action couplings in advance.
5. assigning tasks to actors (controlled/structured perception-action match)

Material for planned

Another set of processes leads to shared representations of co-actors’ tasks and intentions. This requires the ability to keep self and other apart and to relate one’s actions to others’. In the most minimal case, actors represent their own task and a goal as an outcome that they are not going to achieve alone, but with the help of an external force (Vesper, Butterfill, Knoblich, & Sebanz, in press). Often, however, representations of others’ tasks are more detailed, specifying the actions others are going to perform. Sharing at this level exists not only in the eye of the observer, but rather in co-actors’ minds. We refer to this as \*relational sharing??controlled sharing?complementary sharing?

### Joint perceptions

Brennan/Keysar debate -> minimalist vs not minimalist, Tomasello, Butterfill & Apperly, perspective.

### Joint heuristics and joint knowledge

Strategic use of performance parameters: speeding -> sequential constraints, general heuristic to reduce variance

Strategic use of knowledge: Schelling games, knowledge in general, social scripts etc.

# 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?

### *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)*

#### 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)

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).

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)*

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

# Acknowledgements

???

# Figure captions

Figure 1: Basic perception-action couplings, which include entrainment and enable motor 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, these mechanisms 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.