PREFERENCES FOR COSTLY COOPERATION ARE HIGHLY INDIVIDUALIZED

PREFERENCES FOR COSTLY COOPERATION ARE HIGHLY INDIVIDUALIZED: A REPLICATION AND EXTENSION OF CURIONI ET AL. (2022)

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Lay abstract

When deciding how to move or complete a task, we assume people choose actions that are the most rewarding and least costly. Yet, people repeatedly choose to work cooperatively with others despite it being less time-consuming and equally or more rewarding to do the same task alone. This thesis uses quantitative and qualitative analytical techniques to assess the replicability of previous findings and reveal the factors motivating decisions to cooperate. Unlike previous findings, while some people strongly preferred to complete a task in the more costly, cooperative manner, most either preferred to work alone or did not have a preference for either action. Individuals prioritized energetically-focused and social aspects of the task, and to varying degrees. These results suggest that preferences for cooperative action are not random, but are rather highly individualized. While many people want to maximize their instrumental gains, for some, the most valuable reward is simply the friends they make along the way.

Abstract

When deciding between action alternatives, we use information about the relative costs and rewards of each action to choose an appropriate plan. Participants of a recent study by Curioni et al. (2022) showed strong preferences for completing a virtual box-clearing task cooperatively with a partner rather than alone, despite it being more costly. Participants completed the task standing beside each other in close proximity which may have created a social pressure to cooperate through a need to manage one's reputation or a sense of commitment. Here, 50 human pairs, each composed of a "Decision-maker" and "Helper", completed a box-clearing task modelled after Curioni et al. while seated farther away and out of view of one another. In 50% of trials, Decision-makers were forced to complete the task alone or with the Helper. In the remaining 50% of trials, Decision-makers chose to work alone or cooperatively. When working together, participants were required to synchronize their movements without communication nor feedback of their partner's movements. Decision-makers answered open-ended questions regarding why and when they chose to complete the task alone and together. Contrary to the model experiment, participants demonstrated a slight preference for individual action over costly joint action, although these preferences were not significantly different from chance. Inductive thematic analysis revealed two dominant themes: "chose actions with greater instrumental utility" and

"chose actions with greater social value". The identified themes suggest that preferences to cooperate are highly individualized, and that cooperative action seems to provide additional social rewards which may drive preferences for costly cooperation.

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Declaration of academic achievement

Format and organization of thesis

This thesis is prepared in the standard format as outlined in the Guide for the preparation of master's and doctoral theses provided by McMaster University's School of Graduate Studies.

Contributions to content of thesis

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Chapter 1

Literature review

1.1 General introduction

Movement is a fundamental part of the human experience. Coordinated movement allows individuals to interact with one another and with the surrounding world to produce environmental change. Complex surgical procedures, harmonious musical performances, and even a simple handshake are all examples of coordinated movements known as joint actions. Sebanz et al. (2006) define joint actions as coordinated movements between two or more individuals which result in some change in the environment. Such interactions are social in nature and require that the actions of all agents contribute to some common joint outcome or action goal (Sebanz et al., 2006).

The study of joint actions has been of growing interest in recent years as researchers have come to recognize that humans obtain and share information largely through goal-driven social interaction (Obhi & Sebanz, 2011). Such interactions are complex and require additional cognitive processes, from sharing sensorimotor information to making optimal decisions, in order to be successful. Much of what is known in the literature about these cognitive processes and sensorimotor interactions, however, has been determined through studying individuals in isolation, void of social context (Obhi & Sebanz, 2011; Richardson et al., 2008). Though this research has provided foundational knowledge for understanding individual action planning and execution, it is insufficient for describing the basis of social, multi-agent interactions. Current joint action research aims to bridge this gap through exploring the many complexities of motor cognition within social interactions.

This literature review provides a brief overview of the mechanics and motivations driving joint actions, as well as the various ways that joint actions are distributed and executed between agents. It also discusses the computational processes involved in multi-agent decision making, as well as factors that may contribute to interaction partner choice.

1.2 Mechanisms of coordinated movements

When exploring joint actions, it is first important to understand what is occurring at the neurophysiological and cognitive levels. There are two main components of joint actions that should be considered: 1) the action plan and 2) the action goal (Vesper et al., 2017). These components do not act in isolation; one aspect cannot exist without the other. The action goal is a shared joint outcome that all interaction partners work towards by creating and following an action plan. Individuals generate their action plans with both the action goal and their co-actors' actions in mind (Sebanz et al., 2006). This is necessary for successful coordination as it allows interaction partners to understand and predict each other's movements. This section outlines the proposed mechanisms underlying the preparation and production of joint actions.

1.2.1 Representations

Mirror neurons are visuomotor neurons that fire during both action execution and action observation (Rizzolatti & Craighero, 2004). di Pellegrino et al. (1992) first discovered mirror neurons in the frontal and parietal areas of macaque monkeys. They found that the macaques' neural activity while watching others act mirrored neural activity occurring in the same motor regions while they themselves performed similar actions. Such activation was observed while watching both conspecifics and individuals of different species, including humans, perform actions (di Pellegrino et al., 1992; Gallese et al., 1996; Rizzolatti et al., 1996). Researchers suggest that upon observing an action, neurons within the observer's premotor cortex relevant to that action are activated, producing a motor representation of the action (Rizzolatti & Craighero, 2004). Rizzolatti & Craighero (2004) hypothesize that the mirror neuron system transforms visual information into knowledge about movement patterns or action outcomes in the form of motor representations which may help mediate the understanding and imitation of others' actions (Rizzolatti & Craighero, 2004).

Mirror neurons have not been directly observed in humans as this would require the observation of single neuron activation which cannot be captured with the neuroimaging techniques that currently exist (Baars & Gage, 2010). Though activity of individual neurons in human brains cannot be captured, electroencephalogram (EEG) (Cochin et al., 1998; Cochin et al., 1999), transcranial magnetic stimulation (Fadiga et al., 1995, 2005; Hari et al., 1998), and functional magnetic resonance imaging (Buccino et al., 2004; Molenberghs et al., 2012) have captured activation of key motor brain regions during the execution and observation of human movements. Such observations provide neurophysiological and behavioural evidence to support the existence of a mirror neuron system in humans. This regional activation of an individual's motor system while simply watching someone else perform an action is referred to as motor resonance (Rizzolatti & Craighero, 2004). Motor resonance involves the activation of an entire motor system, resembling the functioning of individual mirror neurons but on a regional level, thus supporting the notion of a mirror neuron system in humans.

Researchers have recently determined that in a joint action context, individuals do not just form motor representations while observing their partner or executing their own actions, but also in anticipation of their partner's actions. Prior research has established that late contingent negative variation (CNV) and movement-related potentials (MRPs) are indicators of motor planning and representing the onset of others' actions (Brunia & Damen, 1988; Gaillard, 1977), and that amplitude of these ERPs increases with task complexity (Schevernels et al., 2014). Kourtis et al. (2014) recorded late CNV and MRP amplitudes using EEG while individuals prepared to raise glasses in a clinking motion. Late CNV and MRP amplitudes were greater while individuals planned to raise their glass at the same time as their partner than while planning to raise their glass in a similar manner, but alone (unimanually). Since both tasks required equally complex movements with no interpersonal coordination, we would expect both tasks to require similar motor planning. Therefore, observing greater ERP amplitudes in the joint action task despite the irrelevance of the partner to the task and absence of interpersonal coordination suggests that individuals represent their partner's anticipated actions when completing joint tasks (Kourtis et al., 2014).

Representations in joint actions have been supported at the behavioural level as well through observation of the joint Simon effect (Miss et al., 2022; Sebanz et al., 2003). In a solo Simon task where individuals were responsible for responding correctly to external stimuli with one of two options, they typically exhibited the Simon effect of making slower, less accurate choices during spatially incompatible trials. This effect disappeared when individuals were only responsible for one of the responses (Miss et al., 2022). However, in a joint version where the task was completed in pairs and each partner was responsible for one of the two response options, individuals were inhibited by their partner's actions as indicated by the resurgence of the Simon effect (Miss et al., 2022; Ruys & Aarts, 2010). Again, individuals formed representations of their partner's task despite their partner's role being irrelevant to their own task (Sebanz et al., 2003).

In a similar vein, (Schmitz et al., 2017) conducted a study that required pairs of participants to synchronously reach to and from targets where one partner's path was obstructed by an obstacle while the other's was not. Partners without an obstacle in their path moved as if an obstacle were present in order to synchronously arrive at the target at the same time as their partner. This behaviour indicates that beyond representing a partner's task, individuals represent their partner's task constraints and incorporate them into their own action plans as well in the interest of achieving the joint goal (Schmitz et al., 2017). Forming motor representations appears to be a key component of the action understanding and planning process which can either help or hinder performance of a joint task.

1.2.2 Shared sensorimotor information

The formation of shared representations is facilitated by sharing sensorimotor information via various sensorimotor processes, including joint attention, sensorimotor communication, and prediction. Sharing sensorimotor information gives co-actors insight into the environment they are acting in, as well as how they intend to act within that environment. With this information, co-actors can plan their actions accordingly and ultimately improve their coordination.

Attending to the context of another person's actions, specifically the environmental stimuli they are experiencing, is thought to be a fundamental mechanism behind shared representations as it establishes a so-called "perceptual common ground" between interaction partners (Clark, 1996). Individuals sharing perceptual knowledge creates a link in perceptual experiences, commonly referred to as "joint attention" (Tomasello, 1995). Sebanz et al. (2006) note that establishing a sense of joint attention helps initiate and maintain continuous coordination of movements during joint actions. As described in the study by Schmitz et al. (2017), joint attention is especially helpful for inferring others' action goals and performing joint actions successfully. Though the unobstructed participants in the study could not see their partner's movements, they were aware of the obstacle obstructing their path and received auditory feedback of their partner's target landing. Having this sensory information allowed unobstructed participants to adjust their movements accordingly in order to successfully achieve temporal coordination (Schmitz et al., 2017). Interestingly, the unconstrained participants adjusted their movements regardless of whether they could see their partner's movements or not, suggesting that they were representing their partner's task constraints as opposed to their movements (Schmitz et al., 2017). This further supports the notion that establishing joint attention by sharing details about a co-actor's environment can be just as informative and beneficial for achieving a joint goal as having information about a co-actor's actions.

In real world joint action scenarios, some form of communication is typically available and often required for actors to successfully coordinate their movements. In addition to joint attention where the goal is to establish a shared perspective, communication allows individuals to share updated information about their actions in order to make them easier to understand and predict. When communication is available, the perceptual common ground can be continuously updated (Clark & Krych, 2004). Interaction partners often use learned conventional forms of communication to share instructions, action goals, strategies, and feedback. This could be in the form of verbal or non-verbal language, as well as non-verbal expressions, gestures, and posture (Clark & Krych, 2004; Pezzulo et al., 2019).

Actors may also communicate in a less conventional manner known as sensorimotor communication (SMC). SMC leverages the shared sensorimotor information channel during an interaction to communicate information about an individual's actions including action plans, goals, or intentions (Pezzulo et al., 2019). Information shared via SMC is communicated pragmatically; information is embedded within the action itself. In this sense, actions serve a dual purpose; execution of the desired action while also communicating the intention behind the action. The way people move, such as adjusting their movement velocity or the force they exert, is informative in its own right (Pezzulo et al., 2019). When moving an object with another person, individuals can take advantage of the shared haptic channel to inform their partner of the desired destination of the object, as well as any obstacles encountered along the way that require the actors to change their movement patterns (Pezzulo et al., 2019). In addition to communicating the intention of a current action, agents can also communicate their intentions of future action plans and the expectations of co-actors, such as when dividing the roles of a joint task. In Kucukyilmaz et al. (2011) study, human participants collaboratively shared control over a task with a computer partner. While performing the task, the human participants could communicate their desire or intention of having more or less guidance from the robotic partner by applying less or more force to the device, respectively.

Complementary to understanding an actor's actions while observing them is predicting the outcome of such actions and what the actor will do next. Individuals often use SMC in leader-follower dynamics to help guide interaction partners to their next action. In a xylophone-playing task, people exaggerated their movements when performing with and demonstrating a melody for a novice partner (McEllin et al., 2018). They also adjusted their playing speed depending on whether or not their partner knew the melody that was to be played. Leaders alter their movements to make the intentions of their actions known and their future actions easily predictable (McEllin et al., 2018; Sebanz et al., 2006). This relates back to motor resonance and forming representations in anticipation of someone else's actions. When individuals divide components of a task amongst themselves, they share knowledge of what the other person's role entails. Exhibited in the studies by Schmitz et al. (2017) and Ruys & Aarts (2010), knowing the conditions of a partner's task allows actors to better predict their partner's action outcomes. Individuals also estimate action outcomes through monitoring their own and their partner's performance in their respective tasks. This is demonstrated in a study by van Schie et al. (2004) where actors represented their partner's errors as if they made the error themself (van Schie et al., 2004). When interaction partners cannot attend to each other's task stimuli or environment, or monitor each other's behaviour, task performance often suffers (Clark & Krych, 2004; Skantze et al., 2014). Clark & Krych (2004) created joint action scenarios where one partner directed the other in building Lego models. Builders were slower at building the models when their directing partner could not see their workspace and made more errors when the pair could not monitor each other's voices, facial expressions, gaze or posture. With limited sensorimotor information and feedback, participants were less efficient at completing the task. Skantze et al. (2014) conducted a similar study where humans drew a route on a map by following a robot's verbal instructions. Participants performed the task slower and with more misunderstandings when the robot gazed in a random direction or no gaze information was available compared to when the robot looked at the landmarks it was referring to. Again, monitoring an interaction partner's behaviour was needed for participants to efficiently complete the cooperative task. Though coordination is still possible without information of a partner's perceptual environment, having such knowledge allows for optimal coordination between partners.

1.2.3 Interpersonal and intrapersonal coordination

People coordinate their movements both interpersonally (between multiple people) and intrapersonally (between multiple effectors within the same individual, such as multiple limbs). Consider team sports, like soccer. Interpersonal coordination is required for teammates to synchronize their movements with each other as they progress up the field. At the same time, each person is using intrapersonal coordination to control the movement of their body and the ball. Referring back to the glass clinking study by Kourtis et al. (2014), a third condition in their experiment involved participants clinking two glasses together bimanually. They observed similar ERP amplitudes in the bimanual condition to those observed in the joint-unimanual condition, providing neurological evidence that the planning and anticipation of bimanual actions resembles that of joint actions. This implies that motor representations are similar for bimanual and joint actions.

Inter- and intrapersonal coordination share similar principles of spatiotemporal organization (Schmidt & Richardson, 2008). Effective coordination between limbs and between interacting partners requires temporal and spatial synchronization and stability (Schmidt & Richardson, 2008). Haken, Kelso, and Bunz first proposed the HKB model in 1985 (1985). This is a model of theoretical coordination dynamics originally based on findings of various bimanual experiments which revealed that self-organization is a key component of coordinated intrapersonal movements (Haken et al., 1985). Schmidt & Richardson (2008) later observed self-organizing coordination and dynamic stability in coordinated interpersonal actions as well. Thus, the underlying motor processing of coordinated joint actions closely resembles that of bimanual actions (Schmidt & Richardson, 2008).

Though inter- and intrapersonal coordination share similar fundamental motor mechanisms, there are differences in the availability of information and influence of external factors on the success of either type of coordinated movements. In bimanual actions, neural crosstalk allows some of the force command for one limb to be transmitted to the contralateral limb, despite the existence of separate motor plans for each limb (Cattaert et al., 1999). Although individuals have been observed to unintentionally synchronize their movements (entrainment) during both intra- and interpersonal joint actions, intrapersonal coordinated actions are typically more accurate and spatially and temporally synchronized than interpersonal actions (Schmidt & Richardson, 2008). Kovacs et al. (2020) proposed that this could be due to a stabilizing effect facilitated by crosstalk, creating an advantage for bimanual action over interpersonal joint action. Additionally, in scenarios where communication is limited and degrees of freedom in action alternatives are high, bimanual actions pose an advantage of knowing the intentions and action plans behind each effector's movements. This brings to light an additional disadvantage in coordinated interpersonal movements of needing to predict a co-actor's intentions.

1.3 Decisions to cooperate

In addition to understanding how joint actions occur, it is also important to consider why individuals choose to work with one another and when. This may seem obvious when considering scenarios of survival in which cooperation is required for the task at hand, however, it becomes less clear as to what motivates people to work with others when cooperation is not required or is even a hindrance to achieving the end goal of a task. This section will discuss how individuals evaluate action alternatives to decide on a course of action.

1.3.1 Instrumental cooperation

Researchers have traced joint actions back to the most basic survival behaviours where animals have evolved to forage (C. W. Clark & Mangel, 1986), fight (Green et al., 2022; Martínez-Íñigo et al., 2021), and travel in groups (Berdahl et al., 2018; Milner-Gulland et al., 2011). In such instances, it is advantageous and often necessary to rely on the help of others in order to achieve outcomes that could not otherwise be achieved alone. Humans and closely related primates innately cooperate for survival and when it is necessary for achieving a desired goal (Bullinger et al., 2011; Sussman et al., 2005). However, many activities in life are done in a cooperative manner which are neither survival-based nor entirely necessary.

The voluntary nature of joint actions is two-fold; individuals have voluntary control over their actions and choose to perform such actions in a joint effort. It is intuitive that individuals would choose to act together when the desired outcome is not achievable alone. In scenarios where it is possible to achieve a desired outcome alone, however, researchers posit that it makes sense for individuals to choose joint actions when it is either less costly or more rewarding to the individual than performing the task alone (Curioni et al., 2022; Duguid et al., 2014). This is the concept of maximizing utility, where utility is the perceived usefulness of a behaviour according to a subjective evaluation of worth to the actor (Mosteller & Nogee, 1951). When choosing between action alternatives, it is assumed that actors perform some cost-benefit analysis using a subjective scale of values which assesses the personal worth of different commodities in order to select the most optimal behaviour (Mosteller & Nogee, 1951). Tversky (1967) suggests that the maximization principle and the decomposition hypothesis are fundamental aspects of decision making. The maximization principle states that people choose behaviours that best align with their personal sense of worth or values (Katz & Kahn, 1978; Tversky, 1967). Complementary to this, the decomposition hypothesis states that such personal value can be broken down into simple individual components (Anderson, 2002; Tversky, 1967). In terms of the aforementioned cost-benefit analysis, the potential costs and benefits associated with different actions are the components which when considered together, determine the overall personal value of behaviours.

The Naïve Utility Calculus is a specific utility function which states that at the very basic level, people assume that others make choices by maximizing rewards and minimizing costs (Jara-Ettinger et al., 2016). The function equates the utility of an action plan to the rewards of following the action plan minus the costs of carrying out the action plan (Jara-Ettinger et al., 2016), closely resembling the simple economic profit formula: profit equals revenue minus expenses. The calculus suggests that when given a choice, people assume that others will always decide to optimize their utility (Jara-Ettinger et al., 2016). This is seen in humans as young as 18 months of age who are able to recognize others' subjective desires and infer their preferences accordingly (Repacholi & Gopnik, 1997).

Unlike economic profit, the estimated utility of actions is subjective to the individual and dependent on a variety of factors (Carland et al., 2019). In addition to the direct effort and payoff of the task at hand, individuals must also consider time invested, probability of a successful outcome, and alternative behaviours when choosing an action. All of these factors together contribute to what is known as a reward rate (Carland et al., 2019). Reward rate can be mathematically explained as the reward sensitivity of successful achievement of the desired outcome, multiplied by the risk sensitivity of the action being successful, minus the subjective effort of executing the action, divided by all accounts of time involved in planning and executing the action (Carland et al., 2019). When plotted, reward rate initially increases with time while accuracy, and thus probability of reward, increases with deliberation time. Carland et al. (2019) explain that as improvements in accuracy begin to plateau, the investment of time is no longer as valuable and thus the reward rate begins to decrease. Therefore, for any action, there will always be a time where reward rate is maximal (Carland et al., 2019). Deciding how much time is worth dedicating to an action aligns with Charnov's Marginal Value Theorem which describes animals' commitment to a resource patch before leaving for another (Carland et al., 2019; Charnov, 1976). Rather than exclusively maximizing utility, it appears most optimal to prioritize maximal reward rate when choosing actions, as reward rate accounts for time invested.

There is an interesting application of utility and reward rate in joint actions when trying to rationalize peoples' decisions to cooperate rather than act alone, as the aforementioned factors must be considered from both an individual and joint perspective. Coordinating is also energetically costly in its own right (Diedrichsen et al., 2010; Salimpour & Shadmehr, 2014), so the additional costs associated with coordinating must be taken into account as well. In a study by Török et al. (2019), pairs completed a sequential object-transfer task which required pairs of participants to choose between paths of varying lengths in order to collectively move the object into the end target. The varied path lengths made for varying degrees of effort for each participant within a pair. Path choices indicated whether individuals prioritized their own efficiency, their partner's efficiency, or the overall group's efficiency (coefficiency) while completing the task. They found that individuals prioritized coefficiency over their own individual efficiency, providing an interesting finding in regards to utility and reward rate. It can be inferred that in this task scenario, completing the joint action goal efficiently was of greater value or higher priority to the individual than the efficient completion of their own portion of the task (Török et al., 2019).

1.3.2 Unnecessary cooperation

Expanding on individuals' motivations to cooperate, what separates humans from other animals is their preference to cooperate even when it is not necessary. This preference can be observed as early as three years of age and is especially noteworthy as non-human primates, who also engage in cooperative activity, do not show the same preference for unnecessary joint efforts (Rekers et al., 2011). In addition to relatively neutral scenarios where there are no obvious differences in instrumental costs or gains to acting together or alone, there is also the possibility of a task being more costly to complete together than alone. Recently, Curioni et al. (2022) investigated whether adults prefer to cooperate in a target tapping task where it was not only unnecessary, but also instrumentally costly to act with a partner rather than individually. They concluded that despite joint action being the less effective, suboptimal strategy for achieving the task objective, participants showed a preference for cooperation.

There are numerous potential explanations as to why people make such seemingly suboptimal decisions, many of which relate back to the concept of maximizing utility and reward rate. If the amount of effort or resources required to complete a task is not overtly obvious, people may not perceive the coordination costs they incur to be as detrimental as they truly are (Curioni et al., 2022; Jara-Ettinger et al., 2016). Curioni et al. (2022) followed their initial experiment with a solo control experiment where individuals performed the same target-tapping task, but chose between completing the task unimanually or bimanually. As discussed in the previous section, bimanual actions are representative of interpersonal joint actions from a coordination and motor processing perspective (Kourtis et al., 2014; Schmidt & Richardson, 2008). Where inter- and intrapersonal coordinated actions differ is in the nature of the coordinated movements; joint actions are social interactions while bimanual actions are not. In the solo experiment, the bimanual condition was more instrumentally costly than the unimanual condition, mirroring the instrumental costs of the together condition in the initial experiment. Contrary to the initial experiment, however, individuals showed a preference for unimanual actions, demonstrating that they did perceive the joint condition as being more energetically costly. This suggests that some social factors may have motivated people to cooperate with their partner.

There is currently minimal research investigating the social factors that motivate individuals to interact with one another. Considering the details of the task setup in Curioni et al.'s experiment, some possible participant and task-related variables may have influenced participants' decisions to cooperate. Performing an action with another person may simply be more enjoyable than acting alone (Andreoni & Miller, 1993; Curioni et al., 2022; Fine & Corte, 2017). People may also feel a sense of social pressure to include their partner in an activity when they are in the same room, driven by empathy, a desire to maintain one's reputation (Curioni et al., 2022; Nowak & Sigmund, 2005; Rumble et al., 2010; Wu et al., 2016), or a sense of commitment (Michael et al., 2016b). Individuals may recognize the costly nature of the task and choose to cooperate as a teaching opportunity (Jarrassé et al., 2012). Finally, in a challenging or stress-inducing task, cooperation may be stress-relieving, as suggested by reduced cortisol levels in primates who prefer to cooperate with closely-related conspecifics (Stocker et al., 2020).

1.4 Role distribution in joint actions

To coordinate is to invest efforts in order to achieve shared goals (Van de Ven et al., 1976). Coordination is the basis of all types of interactions. Joint actions may look different depending on the nature of the interaction and how a task is distributed amongst co-actors. The distribution of roles can influence and are influenced by the individual abilities and limitations of actors, their commitment to an activity, their expertise or experience with an activity, and the degree of coordination required for successful completion of an activity.

Jarrassé et al. (2012) proposed a Motor Behaviour Interaction Taxonomy which classifies interactions as either competition, collaboration, or cooperation based on the effort and error each agent experiences. Within this taxonomy, each interaction behaviour type is first defined by the impact of the task on the interacting agents. Antagonistic interactions are deemed competition while agonistic interactions are further classified as either collaboration or cooperation. When engaging in competition, agents are concerned with their own actions and efforts, striving towards achieving individual subtask goals with no common task goal. Individuals may even dedicate effort towards interfering with their opponent as improvement in one agents' performance can hinder the other's. In agonistic interactions, both agents' efforts contribute to this same common task goal and improvement in an individual's subtask leads to improvement in the overall task goal. The distinguishing factor separating collaboration from cooperation is the assignment of partner roles. When individuals collaborate with one another, all agents begin working towards completing the task goal in a symmetric fashion where the effort required for their subtasks is equal. Roles are not assigned prior to beginning the activity but rather emerge spontaneously as the activity unfolds. In contrast, cooperating agents work in uneven roles which are assigned prior to beginning the task. In this sense, while all cooperating agents' efforts contribute to the task goal, their subtasks and the effort required to complete them are not necessarily equal.

1.5 Partner choice in joint actions

When a person decides to perform a joint action, they often also need to decide who they want to perform that joint action with. Various sociological factors relating to personal identity may influence this decision, ranging from surface level demographics such as sex (Balliet et al., 2011) and ethnicity (Chuah et al., 2014) to more subjective physical features (Chen et al., 2012; Krumhuber et al., 2007; Shang & Liu, 2022). Deeper sociological constructs including social status (Boukarras et al., 2021; Levy et al., 2004; Perc & Szolnoki, 2008) and personal, ethical, and spiritual beliefs or values (Chuah et al., 2014; Tomasello et al., 2009) may also be factors in partner choice. People also consider the competence or ability of potential coordination partners when deciding who to work with. This may be determined by others' confidence in the task (McEllin et al., 2022), their skill level (Vaez-Alaei et al., 2022), or their experience with the task or related activities (Vaez-Alaei et al., 2022). The relationship dynamic between partners is another variable to consider, taking interaction history (Li et al., 2008; Rich & Sidner, 1997), relatedness (West et al., 2002), and power dynamics (De Cremer & Tyler, 2007; Grebelsky-Lichtman, 2014) into account.

Many of these traits rely on trust; trusting a partner to perform the task correctly, with their best effort, and with a high degree of care and commitment to their performance (Dirks, 1999; Macy & Skvoretz, 1998). Relating back to utility and reward rate, some of these factors may also influence the perceived rewards or costs of performing an action with another person, dictating not only who people choose to act with, but whether they choose to act with another person at all.

The research area of joint actions, specifically decision making in joint actions, is incredibly interdisciplinary. Aspects of neuroscience help to explain the neurological mechanisms of joint actions while foundational cognitive psychology describes the sensorimotor processing that occurs. Evolutionary and developmental research inform the early survival-related drives for animal interactions. When combined with principles of economics, computational psychology, and the biological physics that govern human movement, theoretical assumptions about utility and human motivations to cooperate can be posed. Behavioural psychology explains the various interaction dynamics and sociological factors that may play a role in how individuals choose to complete joint tasks and who they complete them with. Each discipline brings a necessary perspective, emphasizing the need for a holistic research approach to appreciate the variability of joint actions and all that contributes to their execution.

Though the strength of sociological motivating factors can be quite personal to the individual, it is important to gain a better understanding of variables that can influence the decision to cooperate, the manner in which someone chooses to cooperate, and with whom someone chooses to cooperate. Such factors are currently loosely incorporated in utility and reward rate models. It would be interesting to further specify the influence of sociological variables within these models in an effort to refine our current understanding of optimality and determine the conditions and dynamics under which optimal joint actions occur.

Chapter 2

Introduction

From playing a musical duet, performing a complex surgery, or cheersing beers at the pub, joint actions are fundamental to everyday human life. Joint actions are social interactions where two or more individuals voluntarily coordinate their movements in space and/or time to achieve a common goal (Sebanz et al., 2006). Previous research has examined *how* individuals form representations of (Kourtis et al., 2014; Schmitz et al., 2017) and monitor (Loehr et al., 2013) each other's actions, predict their partner's performance (Wolf et al., 2018), perform joint attention tasks (Constable et al., 2018; McPhee et al., 2016), and use movements to communicate when verbal communication is not an option (Pezzulo et al., 2013; Woźniak & Knoblich, 2022). Yet, we still have both a limited understanding of and lack of theory on *why* individuals choose to engage, or not engage, in joint actions. For instance, it is often obvious when a joint action is required, such as when two small children must carry a big box of toys together. However, an adult may choose to carry the same box alone or might ask a friend to help despite this help not being necessary to successfully move the box. What motivations and thought processes underlie such decisions in social contexts?

When choosing between action alternatives, it has been suggested that individuals weigh the costs they will incur against the potential benefits they could receive (Gallivan et al., 2018; Gordon et al., 2021; Kahneman & Tversky, 2012; Shadmehr et al., 2016). Indeed, individuals tend to optimize their decisions by choosing actions that maximize their rewards while minimizing their costs (e.g., Jara-Ettinger et al., 2016; Todorov, 2004). This behavior is well captured in utility models such as the Naive Utility Calculus (Jara-Ettinger et al., 2016, 2020) wherein the utility (usefulness) of an action is equated to the rewards (direct payoff) of successfully achieving the desired action outcome minus the costs incurred (resources used) while acting. Importantly, these evaluations are subjective and susceptible to social influences (Mosteller & Nogee, 1951; Rangel et al., 2008). Instrumental rewards related to the action outcome include the completion of the task itself, such as the box of toys now being in the desired location, as well as additional rewards the actor may earn for successfully completing the task, such as money or points. Movement-related costs include energy expenditure and biomechanical factors associated with performing the action (Cos et al., 2011, 2014; Moskowitz et al., 2023; Shadmehr et al., 2016; Todorov, 2004). Interestingly, performing a joint action is more costly—both cognitively and motorically—than performing the same action alone as individuals must represent, predict, and/or monitor the performance of their partner (Knoblich et al., 2011; Sebanz et al., 2006; Sebanz & Knoblich, 2021). Such coordinated actions therefore create opportunities for spatial and temporal errors between co-actors that do not occur when acting alone; thus, increasing the overall cost function of joint action. An open question is how individuals decide to engage or not engage in a joint action, and whether this decision is based on principles of optimization and utility.

Curioni et al. (2022) recently explored this question in a series of experiments using a virtual "box clearing" task where it was instrumentally more costly to perform the task with a partner compared to alone. When the task was performed alone, an individual would clear boxes as quickly as possible by tapping them and could clear the boxes in any order. When the task was performed together, the total number of boxes was divided evenly between participants and arranged identically. Without communicating or looking at the other person's workspace, the partners had to clear boxes as quickly as possible by tapping the *same* box within a pre-specified synchrony threshold.[1] Despite joint action being the suboptimal way to complete the task, on the trials where the participant in the Decision-maker role could choose to complete the task alone or together, participants showed a consistent preference for cooperation across experiments. Interestingly, in control experiments where individuals chose between completing the same "box clearing" task either unimanually or bimanually, individuals preferred to complete the task unimanually. That is, participants chose the less costly and more optimal way to perform the task under these conditions. As bimanual actions are thought to be representative of interpersonal actions from a coordination perspective (e.g., Kourtis et al., 2014; Schmidt & Richardson, 2008), the data from Curioni and colleagues (2022) strongly suggest that social factors inherent to joint actions, such as a higher intrinsic reward value assigned to cooperation, may bias the computation of the utility of performing a task with another person. In the joint action version of the task, the two participants were always positioned beside each other (shoulder-to-shoulder) and performed the task on the same touchscreen device (46 in), but within their respective workspaces that were created by dividing the touchscreen in two equal halves. This physical proximity of the participants may have created a social pressure for the Decision-maker to engage in joint action, possibly through a sense of commitment (e.g., Michael et al., 2016b, 2016a) and/or from a need to manage one's reputation (e.g., Nowak & Sigmund, 2005).

[1] In Experiments 1 and 2, the pre-specified time window was 200 ms. In Experiment 3 it was 250 ms and in Experiments 4 and 5 it could be either 120 or 60 ms.

Here, we assessed the replicability of Curioni and colleagues' (2022) finding that humans have a preference to perform a task cooperatively, rather than alone, despite the higher costs of coordinating with a partner. Our experiment was modelled after Experiment 1 of Curioni et al. (2022) and we extend their work in two important ways. First, we used a different task setup that naturally increased the distance between participants as each participant performed the task on separate devices. Second, we queried the participants that were randomly assigned to the Decision-maker role about their thought processes on the trials where they decided to perform the task alone or together with their partner. Based on Curioni et al. (2022), we predicted that participants would show a significant preference for performing the task with their partner compared to chance level (50%). We also predicted that on no-choice trials participants would complete the task faster alone than with a partner and that the time required to complete the task would increase with the number of boxes to clear.

Chapter 3

Methods

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study (Simmons et al., 2012). Data and code are available at https://github.com/cartermaclab/expt_solo-vs-joint-action and the preregistration can be accessed at https://doi.org/10.17605/OSF.IO/EVDP5.

3.1 Participants

A sample of 100 undergraduate and graduate students at McMaster University (50 human pairs, M_{age} = 18.51 years, SD = 2.01) participated in the experiment. Sample size was determined *a priori* as 2.5 times the original sample size in Curioni et al. (2022) based on the recommendations of Simonsohn (2015). All participants self-reported that they were free of sensorimotor impairments and had normal or corrected-to-normal vision. Participants were compensated with $5 CAD or with course-credit for their time. All participants provided written informed consent and the experiment was approved by the McMaster Research Ethics Board.

3.2 Task and apparatus

Participants performed a virtual box clearing task similar to that used in Curioni et al. (2022). In their version, participants cleared boxes by tapping a box with their finger in any order they preferred. In our version, participants cleared boxes by "hitting" a box with their virtual cursor in any order they preferred. Our task was performed using two Kinarm End-Point Labs (Kinarm; Kingston, ON, Canada) that are able to interact with each other in real-time. Each participant of a human pair was seated in an adjustable chair in front of either the left or right End-Point Lab at a height such that their forehead could rest comfortably on the system's padded headrest. This experimental setup naturally positioned the participants out of sight from one another and at a distance of 3.05 m. Each participant grasped the handle of the robotic manipulandum using their preferred hand and made reaching movements in the horizontal plane. A semi-silvered mirror blocked the vision of the upper limb and displayed virtual images from an LCD monitor. On the virtual display, participants saw their respective workspace, a cursor representing their unseen hand, and virtual boxes (i.e., targets) in a grid arrangement. Hand position was recorded at 1000 Hz and stored for offline data analysis.

3.3 Procedure

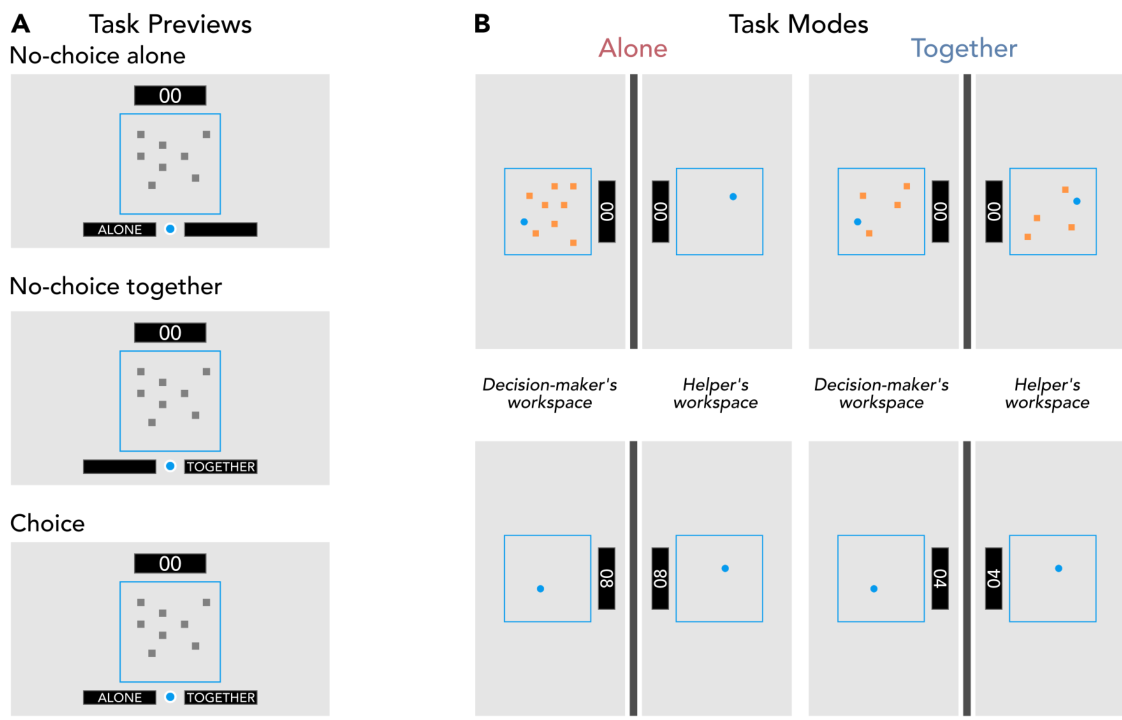
Participant pairs entered the lab and were directed to sit at a desk across from one another to receive verbal and written instructions about the experiment. Within each pair, one participant performed the task in the role of the "Decision-maker" and the other in the role of the "Helper". These roles were assigned randomly and the Kinarm End-Point Lab (left or right) occupied by the Decision-maker was counterbalanced across participants. Consistent with Curioni et al. (2022), we had no hypotheses about the effects of sex and/or gender so pairs were created without controlling for these factors. Participants were instructed that the task goal was for the Decision-maker to collect as many points as possible by clearing boxes from their workspace (1 point per box) within 30 mins. It was made clear that points were not earned for any boxes cleared by the Helper on their respective workspace. However, participants unknowingly completed a fixed number of trials, which required less time to complete than this time limit. Participants were also not permitted to communicate with one another throughout the experiment.

In 50% of trials, the Decision-maker was given the choice to perform the task alone or with the Helper (choice trials). In the remaining 50% of trials, the Decision-maker was forced to do the task alone (no-choice alone; 25% of trials) or together (no-choice together; 25% of trials). The fixed number of no-choice alone and no-choice together trials were included to ensure that each pair of participants experienced the same minimum number of trials in each task mode, irrespective of the Decision-maker's decisions in the choice trials. Within each task mode (i.e., no-choice alone, no-choice together, and choice), we manipulated the number of boxes that were displayed with either four, eight, or 12 boxes. All trial conditions were fully randomized and each number of boxes appeared an equal number of times. All pairs experienced the same randomized order of trial conditions.

The experiment began with four familiarization trials (two no-choice alone and two no-choice together), followed by 180 experimental trials consisting of 90 choice, 45 no-choice alone, and 45 no-choice together in a random order. Each trial began with a preview of the box configuration for the upcoming trial displayed to the Decision-maker (Figure 3.1A). Boxes were gray during the preview. Participants then moved their virtual cursor into the home position. After holding this position for 500 ms, two rectangles appeared at the bottom of the display on opposite sides of the home position. In the choice task mode, the word ALONE appeared in one rectangle and TOGETHER in the other. The Decision-maker would move their cursor into one of the two rectangles to select the task mode they wanted for the upcoming trial. In the no-choice task mode, when the two rectangles appeared only one contained text to indicate the task mode for the upcoming trial. The Decision-maker would then move their virtual cursor into this rectangle. The rectangle that the ALONE and TOGETHER text appeared in was counterbalanced across pairs. Once the Decision-maker moved their cursor into the selected (choice task mode) or the imposed (no-choice task mode) rectangle, the boxes changed from gray to orange, signifying the start of that trial. The trial ended once the last box was cleared or after 100 s elapsed. On alone trials, boxes appeared only in the Decision-maker's workspace and thus, could only be cleared by the Decision-maker. On together trials, the boxes were evenly distributed across each participant's workspace and appeared in the same arrangement (Figure 3.1B). On these trials, both participants had to "hit" boxes in the same grid location with their cursors, within a pre-specified time window of $\leq$ 200 ms. If they "hit" different boxes or did not "hit" the same box within the synchrony threshold, the box remained on the screen until synchronously hit. Participants had no feedback of each other's movements and were not permitted to communicate with each other. One point was awarded for every box cleared from the Decision-maker's workspace. A box above the participant's workspace showed the cumulative number of points earned and was updated at the end of each trial. This design ensured that performing the task together was not only suboptimal in terms of maximizing reward (i.e., points per trial), but also increased movement costs associated with coordinating their actions (i.e., same box in $\leq$ 200 ms) with their partner (Figure 3.1C).

Figure 3.1

Overview of experimental design and task.



C

$$U_{alone} = R_{outcome} - C_{action} = \text{points} - \text{actions}$$

$$U_{together} = [R_{outcome} + R_{coordination}] - [C_{action} + C_{coordination}] = [\text{points}/2 + R_{coordination}] - [\text{actions}/2 + C_{coordination}]$$

Note. Human pairs performed a virtual "box-clearing" task in either the Decision-maker role or the Helper role. At the start of each trial, only the Decision-maker was shown a preview of the target box arrangement for the upcoming trial and two task mode selection boxes **(A)**. In the no-choice trials, the Decision-maker was instructed to select the active task mode selection box (i.e., only one contained text) by moving their cursor into the box. In the choice trials, both task mode selection boxes were active and the Decision-maker was instructed to choose one of the two task modes. Once a task mode was selected, the selection boxes disappeared and the target boxes changed colour from gray to orange **(B)**. This change in colours served as the GO-signal for participants. In alone trials, all boxes shown in the preview remained in the Decision-maker's workspace while the Helper saw an empty workspace. In together trials, the boxes were evenly distributed across each participant's workspace and appeared in the same arrangement. Trials ended once all boxes were cleared or timed out after 100 s. Points (1 per box) were only earned for boxes cleared by the Decision-maker. The utility of performing this task alone versus together **(C)** can be estimated as follows. U is the overall estimated utility of each task mode. $R_{outcome}$ is the expected instrumental reward (i.e., points) of the outcome of an action and C_{action} is the expected instrumental cost of performing an action. As joint actions have additional coodination demands, the utility estimation of acting together includes additional parameters. $R_{coordination}$ is the additional expected non-instrumental rewards that may result from acting together and $C_{coordination}$ is the additional expected coordination costs of acting together.

After participants completed all experimental trials, the Decision-makers were asked a series of open-ended questions regarding their decision-making processes. The Decision-makers answered these questions by typing their responses in a survey form on a laptop that were saved for later analysis. Participants were asked to answer the following questions: a) "When given the choice to do the task alone or together with the Helper, *why* did you choose to complete the task *alone*?", b) "When given the choice to do the task alone or together with the Helper, *when* did you choose to complete the task *alone*?", c) "When given the choice to do the task alone or together with the Helper, *why* did you choose to complete the task *together*?", d) "When given the choice to do the task alone or together with the Helper, *when* did you choose to complete the task *together*?", and e) "Is there anything else you would like to tell us about how you completed the task?". No follow-up questions were asked regarding participants' responses. Participants required approximately five minutes to complete this part of the experiment.

3.4 Data analysis

3.4.1 Quantitative analysis

Our primary outcome variable was the proportion of trials in the choice task mode where the Decision-makers selected to perform the task with the Helper (i.e., to perform a joint rather than solo action). Our second outcome variable was trial completion time for no-choice trials, which was the interval of time between the boxes turning orange and the last box being cleared. Alpha was set to .05 for all statistical tests, which are described below. Corrected degrees of freedom using the Greenhouse-Geisser method are always reported when appropriate. Generalized eta squared (η^2_G) is reported as an effect size for all omnibus tests. Post-hoc comparisons were performed using the Holm-Bonferroni approach to adjust for multiple comparisons. Statistical analyses were conducted using R (Version 4.4.1; R Core Team, 2021).

3.4.2 Qualitative analysis

An inductive thematic content analysis (Braun & Clarke, 2006) was conducted to identify, analyze, and report themes within the open-ended questionnaire data. The analysis was conducted in a stepwise process. First, the primary coder (M.L.) read through all participants' responses to the open-ended questions and made initial notes of the content of the data. This allowed the coder to become familiar with the data, specifically the depth and breadth of the responses. Next, the coder systematically worked through the entire data set, identifying segments of responses (i.e., sentences, phrases, or individual words) that shared similar ideas or topics. While identifying such segments, the coder generated labels (initial codes) for each common idea or topic. The coder then generated various levels of themes by considering how different codes could be combined to support overarching themes. The coder first consolidated the initial codes into initial themes. These initial themes were further combined to form intermediate themes. Finally, the intermediate themes were once more grouped into a final set of higher order themes. The operational definition, an example of a participant's response, and the number of responses for each higher order theme can be found in Table 3.1.

To ensure the validity of the identified themes and a reliable portrayal of the data by the primary coder, intercoder reliability was measured during the thematic analysis process following the guidelines of O'Connor & Joffe (2020). This process involved comparing the agreement of coding between two coders. After grouping the initial codes into five final themes, the primary coder provided a comparison coder (J.T.) with a random selection of 50% of the codes, as well as a list of the five final themes and the respective operational definitions. The comparison coder was instructed to sort each code into one of the five themes to the best of their knowledge using the theme names and definitions. A comparison analysis was performed to determine intercoder reliability between coders, which resulted in a Cohen's κ of .88. This value is larger than the recommended minimum value of .80

(Hruschka et al., 2004), suggesting strong intercoder reliability and confirming that the primary coder reliably represented the data within the five final themes.

Table 3.1

The five final themes from the thematic analysis, as well as their operational definitions, intermediate and initial themes if applicable, and an example of a participant's response.

Final theme	Definition	Intermediate theme	Initial theme	Example
Chose action with greater instrumental utility	Made decisions with the intention of reducing the time or energy needed to complete the task, and/or increasing the amount of points that could be earned.	Reduced instrumental costs	Maximized speed	"I decided to do all the optional tasks alone because I knew it would be faster..." (Participant 212)
			Minimized move-ment	"I attempted to complete the task in the most effective and quickest way, moving the handle with the shortest distance possible." (Participant 111)

Reduced cognitive costs	Minimized decisions required	"I chose to do the task alone when there were many boxes that were far away from each other as I knew it would be difficult to choose the same boxes as the helper." (Participant 101)
	Minimized difficult coordina-tion	"[I chose alone] because it was more reliable and gave more points, it eliminated the variable of having to depend on another person’s timing and thinking." (Participant 107)

Minimized task constraints	Completed the task in the "easiest way"	"It was easier to complete the task alone" (Participant 404)
	Considered the spatial arrange-ment of the boxes	"[I chose together] when there was not as high of a concentration of squares, but also when they were in close proximity with each other." (Participant 203)
Maximized instrumental rewards	NA	"I chose to complete the task alone when I realized that the number of points I got from working together was not as much as working alone." (Participant 412)

Chose actions with greater social value	Made decisions that were motivated by enhancing their own and/or their partner's experience	Maximized intrinsic rewards	NA	"I found it more fun and interesting when I had to complete the task together because you can see how similarly or differently you and your partner think and what each person's first instinct is." (Participant 312)
		Prosocial behaviour	Empathy	"[I chose together] because I felt bad for my partner if he was left with nothing to do" (Participant 102)

			Fairness	"I chose to do the task together when I had done a few trials alone. I thought that my partner would be upset if I did a bunch of the trials on my own just to achieve more points, so I would sometimes choose to do them with her to make it more fair." (Participant 410)
Flexibility in decision strategy	Open to changing their decisions throughout the experiment	NA	NA	"There were some instances where I felt me and the helper changed the way we were slicing the squares to try to imitate each other..." (Participant 211)

Planned movement path	Discussed their own individual directional patterns they typically moved in and/or the order they planned to clear boxes in	NA	NA	"I noticed I tended to hit the boxes in a circular motion starting from the one closest to me, moving outwards, then returning to the starting area." (Participant 309)
Made reliable decisions	Made decisions knowing they could perform the task consistently well in that task mode	NA	NA	"[I chose alone] because it was more reliable and gave more points, it eliminated the variable of having to depend on another person's timing and thinking." (Participant 107)

Chapter 4

Results

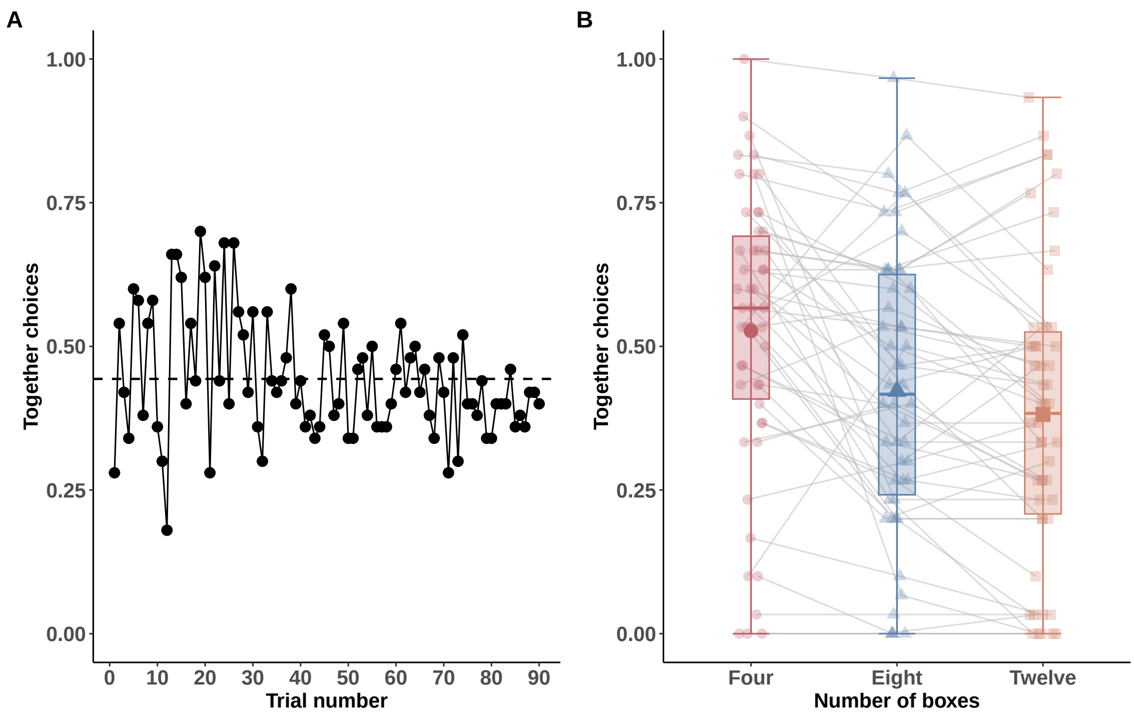
4.1 Quantitative analyses

Participants showed a slight preference of acting alone (M = 0.56, SD = 0.23) compared to joint action (Figure 4.1A). A two-tailed Wilcoxon signed-rank test comparing the mean proportion of alone choices against a 50% chance level was not significant, V = 799.5, p = .112, r = -.225 [-.417, -.036]. This suggests that although participants chose to perform the task alone more frequently than together, their choices were no different than choosing at random.

We performed an exploratory analysis on the proportion of together choices for each box number condition using a one-way repeated measures ANOVA. Participants chose to perform the task together more often when there were fewer boxes to clear, $F(2, 98) = 16.425$, $p < .001$, $\eta^2_G = .057$ (Figure 4.1B). The mean proportion of together choices was greater for 4 boxes than all other numbers of boxes (p's < .002), and for 8 boxes than 12 boxes ($p < .03$).

Figure 4.1

Mean proportion of together choices on choice trials.

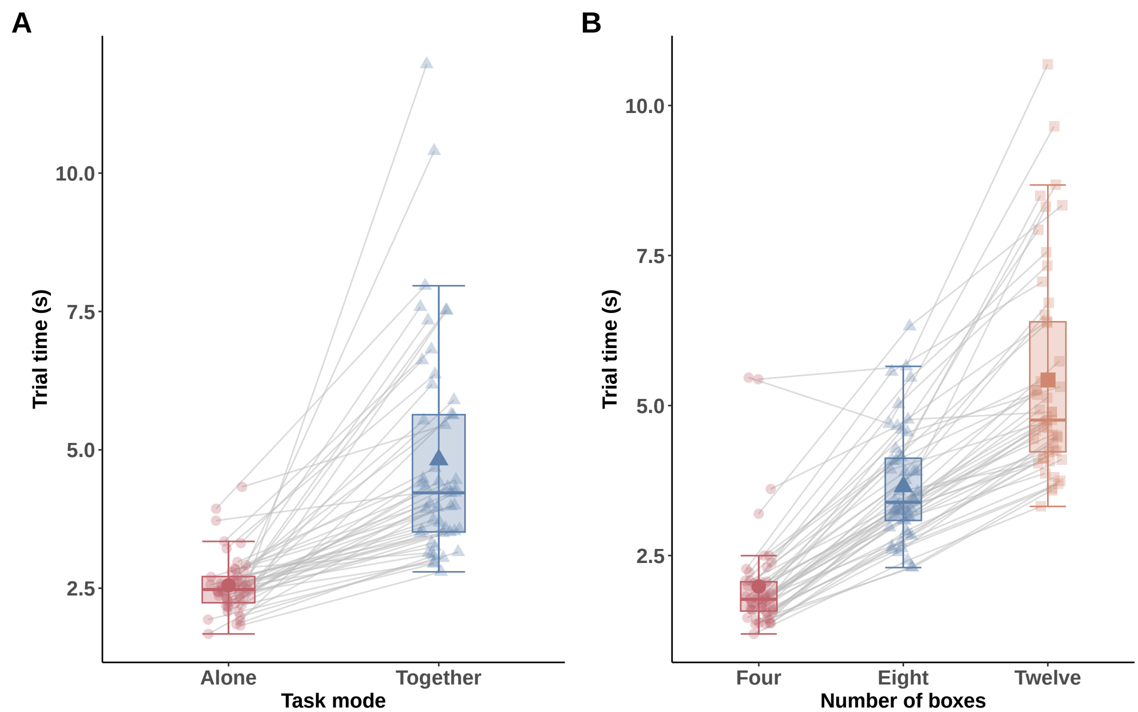


Note. Trial-by-trial changes in the mean proportion of together choices across participants **(A)**. There is a more fluctuation during the early trials compared to the later trials. The horizontal dashed line represents the mean collapsed across trials. Boxplots of the proportion of together choices as a function of the number of boxes on choice trials **(B)**. Boxplots represent 25th, 50th, and 75th percentiles, and the mean for each condition is also shown. Grey lines connect individual participants' mean proportion of together choices for each box number condition.

We analyzed mean trial time using a 2 Task Mode (Alone, Together) x 3 Number of Boxes (4, 8, 12) repeated measures ANOVA. Participants were faster at performing the task alone (M = 2.55 s, SD = 0.52) compared to together (M = 4.82 s, SD = 1.95), which was supported by a significant main effect of Task Mode, $F(1, 49) = 74.332$, $p < .001$, $\eta_G^2 = .323$ (Figure 4.2A). Additionally, participants performed the task faster when there were fewer boxes to clear, $F(2, 98) = 266.514$, $p < .001$, $\eta_G^2 = .422$ (Figure 4.2B). Participants were significantly faster at clearing 4 boxes than all other numbers of boxes (p's < .001), and 8 boxes than 12 boxes ($p < .001$). There was also a significant Task Mode × Number of Boxes interaction, $F(2, 98) = 56.570$, $p < .001$, $\eta_G^2 = .130$, where participants were significantly faster at performing the task alone than together with all numbers of boxes (p's < .001), with 4 boxes than all other numbers of boxes in both task modes (p's < .001), and with 8 boxes than 12 boxes in both task modes (p's < .001).

Figure 4.2

Time required to clear all boxes on no-choice trials.



Note. Boxplots of trial time (s), which was the interval of time between the boxes turning orange and the last box being cleared, for no-choice trials as a function of task mode **(A)** and number of boxes **(B)**. Participants were much faster when acting alone compared to together and trial time increased as the number of boxes increased. Boxplots represent 25th, 50th, and 75th percentiles, and the mean for each condition is also shown. Grey lines connect individual participants' mean trial time for task modes and number of boxes.

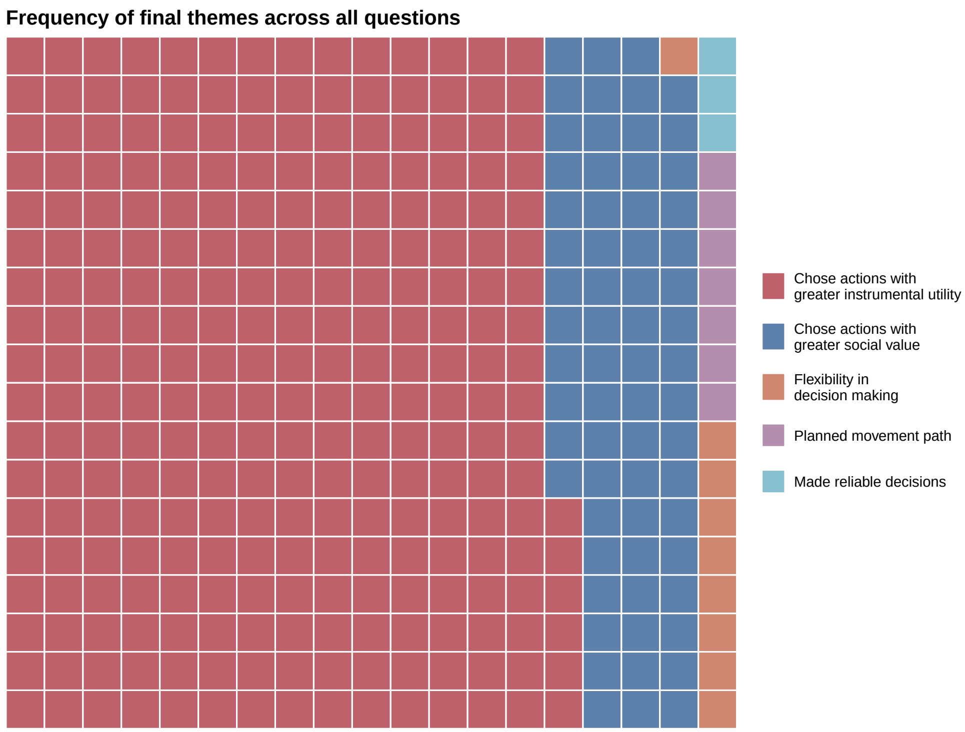
4.2 Qualitative analyses

Five final themes were identified (Figure 4.3), which represented participants' reasoning behind their decisions: a) chose actions with greater instrumental utility, b) chose actions with greater social value, c) made reliable decisions, d) flexibility in decision strategy, and e) planned movement path. The dominant reasoning was "chose actions with greater instrumental utility" (n = 258), followed by "chose actions with greater social value" (n = 65). The other three themes prevailed to similar extents, with the least supported theme being "made reliable decisions" (n = 3).

The two most prominent themes were each composed of several intermediate and initial themes. Within the first theme, "chose actions with greater instrumental utility", participants expressed desires to: (a) reduce instrumental costs, (b) reduce cognitive costs, (c) minimize task constraints, and (d) maximize instrumental rewards. Reducing instrumental costs included ideas of *maximizing speed* and *minimizing movement*, while efforts to reduce cognitive costs included *minimizing the amount of decisions required* and *minimizing difficult coordination*. Participants minimized task constraints by *completing the task in the "easiest" way*, and *considering the spatial arrangement of the boxes*, looking to prioritize efficiency and complete the task with ease. These intermediate themes reflect the separate cost and reward components of instrumental utility, and highlight the complexity of the costs associated with action alternatives. Within the second theme, "chose actions with greater social value", participants reported making efforts to: (a) maximize intrinsic rewards and (b) engage in prosocial behaviour. Prosocial behaviours included acts of *empathy* and *fairness*, taking the Helper's feelings or perspectives into account, and choosing the task condition with the intention of being inclusive to their partner.

Figure 4.3

Frequency of the global themes derived from participant's responses through thematic analysis.



Note. Waffle plot showing the distribution of the five final themes across response to all five open-ended questions. Each square represents a code (single unit of information) aligning with one of the five final themes. The dominant theme was "chose actions with greater instrumental utility" (red, n = 258), followed by "chose actions with greater social value" (blue, n = 65). The remaining themes of "flexibility in decision making" (orange, n = 9), "planned movement path" (purple, n = 7), and "made reliable decisions" (teal, n = 3) were far less common.

Chapter 5

Discussion

Our main finding was that participants showed a modest preference for solo action over joint action, which is opposite to what Curioni et al. (2022) found. Although this preference for solo action was not significantly different from chance levels, we did find that these preferences varied considerably at the individual level (range: 0.033%-100%). This was also evident from the participants' responses on the open-ended questionnaire. Interestingly, the slight preference we found for solo action over joint action is less than what would be expected based solely on principles of utility and optimization (Jara-Ettinger et al., 2016, 2020; Shadmehr et al., 2016; Todorov, 2004). Thus, in line with Curioni et al. (2022), our findings suggest that humans may assign additional reward value to performing actions with another person.

Our failure to replicate a preference for joint action even when it is more costly was surprising given the robustness of this effect across multiple experiments in Curioni et al. (2022). Importantly, this difference cannot be attributed to a failure on our part of not implementing a version of the box-clearing task wherein performing the task together was both more costly and suboptimal. That is, less points could only ever be earned on together trials and all Decision-makers were, on average, significantly slower when performing the task together compared to alone (see Figure 4.2A). In contrast, there was a small subset of participants in Experiment 1 of Curioni et al. (2022) that were actually faster, on average, when performing the task with their Helper compared to alone. One possibility is that it is this subset of participants that drove the effect as these participants were able to reduce their coordination costs and clear boxes more efficiently through joint action. Based on the data from Experiment 4 of Curioni et al. (2022), we think this is an unlikely explanation as the strong preference for joint action was found; yet, similar to our data all Decision-makers, on average, were slower at clearing boxes with their partner compared to alone. We, instead, attribute our conflicting results to the differences in the physical proximity of participants between studies. When human pairs act on the same device beside one another, as in Curioni et al. (2022), it is very likely that the Decision-makers experienced increased pressure to cooperate, presumably through a desire to manage one's reputation (Nowak & Sigmund, 2005; Wu et al., 2016) or a heightened sense of commitment (Michael et al., 2016b; Michael, 2022). Merely positioning participant pairs on separate devices and at a distance of approximately 3 m from each other flipped the effect to a small preference for solo action (56% in our experiment versus the 76% preference for joint action in Curioni et al. (2022)). Nevertheless, participants in our experiment self-reported empathy (e.g., Rumble et al., 2010) and fairness (e.g., Székely & Michael, 2023) as reasons for choosing to perform the task with the Helper, suggesting that social pressures to cooperate may have still been at play with our setup, but to a lesser extent. Further research is needed to better understand the influence of these social factors on the decision to engage, or not engage, in joint action, such as having participants in separate rooms akin to playing a game online or having participants perform the task in both the Decision-maker and Helper roles.

Although the mean proportion of choosing solo trials across participants was not significantly different from chance, there was considerable variability between participants. In fact, a subset of participants always chose to perform the task alone whereas one participant chose to perform the task together on nearly every opportunity (see Figure 4.1B). We suggest that participants' choices were in fact not random and instead reflect rather highly individualized preferences. In support of this, our thematic analysis revealed that no participant described making exclusively random or unrationalized decisions—each participant self-reported at least one deliberate reason within their responses. Thus, if some kind of generic additional reward value is assigned to performing a task with another person, it may largely depend on the individual and/or socio-cultural and psychological variables not explored in the current experiment. Motivation measures, such as the Balanced Inventory of Desirable Responding (Paulhus, 1998) or the Ring Measure of Social Values Liebrand & McClintock (1988)], as well as personality inventories and other validated scales that assess individual differences, could be implemented in future research to better understand the intersectionality of these factors (Appelt et al., 2011).

The most prominent higher order theme identified through our thematic analysis was "chose actions with greater instrumental utility". The sub themes within this category revealed that the Decision-makers were mindful of the task goal (i.e., earn as many points as possible) and often aimed to maximize the utility of their actions when making their decisions. Participants frequently reported wanting to complete the task in the fastest way (overwhelmingly perceived to be the alone condition) or choosing the task condition they thought would require the least amount of movement. This behaviour aligns with the Naive Utility Calculus (Jara-Ettinger et al., 2016, 2020); however, if these participants exclusively considered the instrumental factors of the action alternatives (e.g., points earned, time spent, actions required, etc), we would expect to see a much greater proportion of alone trials than we observed in the choice trials. Many participants also described choosing to work together when there were fewer boxes to clear as they perceived the task to be easier compared to when there were more boxes. With more boxes, participants described it would not only be difficult to select the same box as the Helper, but also coordinate their movements more times. In line with this, we did find that participants made significantly less together choices as the number of boxes to clear increased. Being able to predict an interaction partner's behaviour is an important mechanism for successful coordination (Sebanz et al., 2006). Although the identical arrangement of boxes in each workspace would allow partners to share representations of the task, the unspecified order that the boxes could be cleared made it difficult for participants to predict each other's movement path. Future work should focus on the relationship between individual costs and joint costs during joint action.

Despite the abundance of utility-centered participant responses in our thematic analysis, our data, together with that of Curioni and colleagues (2022), strongly suggest that other factors currently unaccounted for in the utility calculus may outweigh instrumental factors and motivate individuals to engage in costly joint action even when it is unnecessary. This could be represented by a *cooperation reward* variable in the calculus (Curioni et al., 2022); an idea that is supported by our second prominent theme of "chose actions with greater social value". For example, participants described working together as being intrinsically rewarding and that they felt motivated by the enjoyment and enrichment they experienced from the added challenge of coordinating. Others acknowledged the prosocial benefits (Eisenberg et al., 2015) associated with choosing to perform the task together with their partner (e.g., Michael et al., 2020; Obhi & Sebanz, 2011; van der Wel et al., 2021). These individuals empathized with the Helper, choosing together when they felt bad that their partner was left doing nothing or had not participated in a while. This resulted in some participants balancing the distribution of alone and together trials throughout the experiment as a way to be fair towards their partner. Interestingly, these participants did acknowledge that they incurred additional costs and reduced (instrumental) benefits by working together; therefore, the value derived from making the task more fair was oftentimes strong enough to offset the weight of the instrumental factors in the task.

Chapter 6

Conclusion

A possible limitation of our experiment is our use of a convenience sample of undergraduate students; thus, some participant pairs may have already been familiar with one another compared to others, or complete strangers. Individuals may be more inclined to interact with people they know or have previously had positive experiences working with (Hinds et al., 2000; Zander & Havelin, 1960), as a means to increase the predictability of others' actions. Similarly, partners briefly interacted with one another upon entering the lab and sat across from one another while receiving experimental instructions. These brief social interactions, such as greeting (Sandstrom, 2023) and making eye contact (Wesselmann et al., 2012) could have elicited feelings of social connectedness. While it may be beneficial in future research to control these factors, we argue that it was more ecologically valid to allow these brief moments of interaction to occur at the start of the experiment. Similar to Curioni et al. (2022), our participant pairs were created randomly without controlling for sex, gender, age, or ethnicity. Demographics and identification with co-actors have been shown to impact decisions to cooperate (Chen et al., 2012; e.g., Chuah et al., 2014; Krumhuber et al., 2007; Levy et al., 2004), ability to coordinate (Boukarras et al., 2021), and partner choice in interactive tasks (Chuah et al., 2014; Krumhuber et al., 2007). Exploring the influence of these factors in future research may have important practical implications, especially in workplace settings.

In conclusion, we did not find a strong preference for costly cooperative action like that observed by Curioni et al. (2022). Instead, we found a slight preference for choosing individual action, but this was much lower than would be expected if these choices were solely guided by principles of optimization and utility. Our quantitative and qualitative data add further support to the idea that additional rewards are derived from the social nature of joint action (e.g., Curioni et al., 2022) and that these preferences are highly individualized.

References

Anderson, J. R. (2002). Spanning seven orders of magnitude: A challenge for cognitive modeling. *Cognitive Science*, *26*(1), 85–112.

Andreoni, J., & Miller, J. H. (1993). Rational cooperation in the finitely repeated prisoner's dilemma: Experimental evidence. *The Economic Journal*, *103*(418), 570–585.

Appelt, K. C., Milch, K. F., Handgraaf, M. J. J., & Weber, E. U. (2011). The Decision Making Individual Differences Inventory and guidelines for the study of individual differences in judgment and decision-making research. *Judgment and Decision Making*, *6*(3), 252–262. https://doi.org/10.1017/S1930297500001455

Baars, B. J., & Gage, N. M. (2010). *Cognition, brain, and consciousness: Introduction to cognitive neuroscience*. Academic Press.

Balliet, D., Li, N. P., Macfarlan, S. J., & Van Vugt, M. (2011). Sex differences in cooperation: A meta-analytic review of social dilemmas. *Psychological Bulletin*, *137*(6), 881.

Berdahl, A. M., Kao, A. B., Flack, A., Westley, P. A., Codling, E. A., Couzin, I. D., Dell, A. I., & Biro, D. (2018). Collective animal navigation and migratory culture: From theoretical models to empirical evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1746), 20170009.

Boukarras, S., Era, V., Aglioti, S. M., & Candidi, M. (2021). Competence-based social status and implicit preference modulate the ability to coordinate during a joint grasping task. *Scientific Reports*, *11*(1), 5321. https://doi.org/10.1038/s41598-

021-84280-z

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.

Brunia, C. H. M., & Damen, E. J. P. (1988). Distribution of slow brain potentials related to motor preparation and stimulus anticipation in a time estimation task. *Electroencephalography and Clinical Neurophysiology*, *69*(3), 234–243. https://doi.org/10.1016/0013-4694(88)90132-0

Buccino, G., Vogt, S., Ritzl, A., Fink, G. R., Zilles, K., Freund, H.-J., & Rizzolatti, G. (2004). Neural circuits underlying imitation learning of hand actions: An event-related fMRI study. *Neuron*, *42*(2), 323–334.

Bullinger, A. F., Melis, A. P., & Tomasello, M. (2011). Chimpanzees, Pan troglodytes, prefer individual over collaborative strategies towards goals. *Animal Behaviour*, *82*(5), 1135–1141. https://doi.org/10.1016/j.anbehav.2011.08.008

Carland, M. A., Thura, D., & Cisek, P. (2019). The Urge to Decide and Act: Implications for Brain Function and Dysfunction. *The Neuroscientist*, *25*(5), 491–511. https://doi.org/10.1177/1073858419841553

Cattaert, D., Semjen, A., & Summers, J. J. (1999). Simulating a neural cross-talk model for between-hand interference during bimanual circle drawing. *Biological Cybernetics*, *81*(4), 343–358. https://doi.org/10.1007/s004220050567

Charnov, E. L. (1976). Optimal foraging, the marginal value theorem. *Theoretical Population Biology*, *9*(2), 129–136. https://doi.org/10.1016/0040-5809(76)90040-X

Chen, J., Zhong, J., Zhang, Y., Li, P., Zhang, A., Tan, Q., & Li, H. (2012). Electrophysiological correlates of processing facial attractiveness and its influence on cooperative behavior. *Neuroscience Letters*, *517*(2), 65–70. https://doi.org/10.1016/j.neulet.2012.02.082

Chuah, S.-H., Hoffmann, R., Ramasamy, B., & Tan, J. H. (2014). Religion, ethnicity and cooperation: An experimental study. *Journal of Economic Psychology*, *45*, 33–43.

Clark, C. W., & Mangel, M. (1986). The evolutionary advantages of group foraging. *Theoretical Population Biology*, *30*(1), 45–75.

Clark, H. H. (1996). *Using language*. Cambridge university press.

Clark, H. H., & Krych, M. A. (2004). Speaking while monitoring addressees for understanding. *Journal of Memory and Language*, *50*(1), 62–81. https://doi.org/10.1016/j.jml.2003.08.004

Cochin, S., Barthelemy, C., Lejeune, B., Roux, S., & Martineau, J. (1998). Perception of motion and qEEG activity in human adults. *Electroencephalography and Clinical Neurophysiology*, *107*(4), 287–295. https://doi.org/10.1016/S0013-4694(98)00071-6

Cochin, S., Barthelemy, C., Roux, S., & Martineau, J. (1999). Observation and execution of movement: Similarities demonstrated by quantified electroencephalography. *European Journal of Neuroscience*, *11*(5), 1839–1842.

Constable, M. D., Pratt, J., & Welsh, T. N. (2018). "Two minds don't blink alike": The attentional blink does not occur in a joint context. *Frontiers in Psychology*, *9*, 1714.

Cos, I., Bélanger, N., & Cisek, P. (2011). The influence of predicted arm biomechanics on decision making. *Journal of Neurophysiology*, *105*(6), 3022–3033. https://doi.org/10.1152/jn.00975.2010

Cos, I., Duque, J., & Cisek, P. (2014). Rapid prediction of biomechanical costs during action decisions. *Journal of Neurophysiology*, *112*(6), 1256–1266. https://doi.org/10.1152/jn.00147.2014

Curioni, A., Voinov, P., Allritz, M., Wolf, T., Call, J., & Knoblich, G. (2022). Human adults prefer to cooperate even when it is costly. *Proceedings of the Royal Society B: Biological Sciences*, *289*(1973), 20220128. https://doi.org/10.1098/rspb.2022.0128

De Cremer, D., & Tyler, T. R. (2007). The effects of trust in authority and procedural fairness on cooperation. *Journal of Applied Psychology*, *92*, 639–649. https://doi.org/10.1037/0021-9010.92.3.639

di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: A neurophysiological study. *Experimental Brain Research*, *91*(1), 176–180. https://doi.org/10.1007/BF00230027

Diedrichsen, J., Shadmehr, R., & Ivry, R. B. (2010). The coordination of movement: Optimal feedback control and beyond. *Trends in Cognitive Sciences*, *14*(1), 31–39.

Dirks, K. T. (1999). The Effects of Interpersonal Trust on Work Group Performance. *Journal of Applied Psychology*, *84*(3), 445–455.

Duguid, S., Wyman, E., Bullinger, A. F., Herfurth-Majstorovic, K., & Tomasello, M. (2014). Coordination strategies of chimpanzees and human children in a Stag Hunt game. *Proceedings of the Royal Society B: Biological Sciences*, *281*(1796), 20141973.

Eisenberg, N., Eggum, N. D., & Spinrad, T. L. (2015). 114The Development of Prosocial Behavior. In D. A. Schroeder & W. G. Graziano (Eds.), *The Oxford Handbook of Prosocial Behavior* (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780195399813.013.008

Fadiga, L., Craighero, L., & Olivier, E. (2005). Human motor cortex excitability during the perception of others' action. *Current Opinion in Neurobiology*, *15*(2), 213–218.

Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: A magnetic stimulation study. *Journal of Neurophysiology*, *73*(6), 2608–2611.

Fine, G. A., & Corte, U. (2017). Group pleasures: Collaborative commitments, shared narrative, and the sociology of fun. *Sociological Theory*, *35*(1), 64–86.

Gaillard, A. (1977). The late CNV wave: Preparation versus expectancy. *Psychophysiology*, *14*(6), 563–568.

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, *119*(2), 593–609.

Gallivan, J. P., Chapman, C. S., Wolpert, D. M., & Flanagan, J. R. (2018). Decision-making in sensorimotor control. *Nature Reviews Neuroscience*, *19*(9), 519–534. https://doi.org/10.1038/s41583-018-0045-9

Gordon, J., Maselli, A., Lancia, G. L., Thiery, T., Cisek, P., & Pezzulo, G. (2021). The road towards understanding embodied decisions. *Neuroscience & Biobehavioral Reviews*, *131*, 722–736. https://doi.org/10.1016/j.neubiorev.2021.09.034

Grebelsky-Lichtman, T. (2014). Parental Patterns of Cooperation in Parent–Child Interactions: The Relationship Between Nonverbal and Verbal Communication. *Human Communication Research*, *40*(1), 1–29. https://doi.org/10.1111/hcre.12014

Green, P., Thompson, F. J., & Cant, M. A. (2022). Fighting force and experience combine to determine contest success in a warlike mammal. *Proceedings of the National Academy of Sciences*, *119*(25), e2119176119.

Haken, H., Kelso, J. A. S., & Bunz, H. (1985). A theoretical model of phase transitions in human hand movements. *Biological Cybernetics*, *51*(5), 347–356. https://doi.org/10.1007/BF00336922

Hari, R., Forss, N., Avikainen, S., Kirveskari, E., Salenius, S., & Rizzolatti, G. (1998). Activation of human primary motor cortex during action observation: A neuromagnetic study. *Proceedings of the National Academy of Sciences*, *95*(25), 15061–15065. https://doi.org/10.1073/pnas.95.25.15061

Hinds, P. J., Carley, K. M., Krackhardt, D., & Wholey, D. (2000). Choosing Work Group Members: Balancing Similarity, Competence, and Familiarity. *Organizational Behavior and Human Decision Processes*, *81*(2), 226–251. https://doi.org/10.1006/obhd.1999.2875

Hruschka, D. J., Schwartz, D., St.John, D. C., Picone-Decaro, E., Jenkins, R. A., & Carey, J. W. (2004). Reliability in Coding Open-Ended Data: Lessons Learned from HIV Behavioral Research. *Field Methods*, *16*(3), 307–331. https://doi.org/10.1177/1525822X04266540

Jara-Ettinger, J., Gweon, H., Schulz, L. E., & Tenenbaum, J. B. (2016). The Naïve Utility Calculus: Computational Principles Underlying Commonsense Psychology. *Trends in Cognitive Sciences*, *20*(8), 589–604. https://doi.org/10.1016/j.tics.2016.05.011

Jara-Ettinger, J., Schulz, L. E., & Tenenbaum, J. B. (2020). The Naïve Utility Calculus as a unified, quantitative framework for action understanding. *Cognitive Psychology*, *123*, 101334. https://doi.org/10.1016/j.cogpsych.2020.101334

Jarrassé, N., Charalambous, T., & Burdet, E. (2012). A Framework to Describe, Analyze and Generate Interactive Motor Behaviors. *PLOS ONE*, *7*(11), e49945. https://doi.org/10.1371/journal.pone.0049945

Kahneman, D., & Tversky, A. (2012). Prospect Theory: An Analysis of Decision Under Risk. In *Handbook of the Fundamentals of Financial Decision Making: Vols. Volume 4* (pp. 99–127). WORLD SCIENTIFIC. https://doi.org/10.1142/9789814417358_0006

Katz, D., & Kahn, R. L. (1978). *The social psychology of organizations* (Vol. 2). wiley New York.

Knoblich, G., Butterfill, S., & Sebanz, N. (2011). Psychological research on joint action: Theory and data. *Psychology of Learning and Motivation*, *54*, 59–101.

Kourtis, D., Knoblich, G., Woźniak, M., & Sebanz, N. (2014). Attention Allocation and Task Representation during Joint Action Planning. *Journal of Cognitive Neuroscience*, *26*(10), 2275–2286. https://doi.org/10.1162/jocn_a_00634

Kovacs, A. J., Wang, Y., & Kennedy, D. M. (2020). Accessing interpersonal and intrapersonal coordination dynamics. *Experimental Brain Research*, *238*(1), 17–27. https://doi.org/10.1007/s00221-019-05676-y

Krumhuber, E., Manstead, A. S., Cosker, D., Marshall, D., Rosin, P. L., & Kappas, A. (2007). Facial dynamics as indicators of trustworthiness and cooperative behavior. *Emotion*, *7*(4), 730.

Kucukyilmaz, A., Sezgin, T. M., & Basdogan, C. (2011). Conveying intentions through haptics in human-computer collaboration. *2011 IEEE World Haptics Conference*, 421–426.

Levy, I., Kaplan, A., & Patrick, H. (2004). Early Adolescents' Achievement Goals, Social Status, and Attitudes Towards Cooperation with Peers. *Social Psychology of Education*, *7*(2), 127–159. https://doi.org/10.1023/B:SPOE.0000018547.08294.b6

Li, D., Eden, L., Hitt, M. A., & Ireland, R. D. (2008). Friends, Acquaintances, or Strangers? Partner Selection in R&D Alliances. *Academy of Management Journal*, *51*(2), 315–334. https://doi.org/10.5465/amj.2008.31767271

Liebrand, W. B., & McClintock, C. G. (1988). The ring measure of social values: A computerized procedure for assessing individual differences in information processing and social value orientation. *European Journal of Personality*, *2*(3), 217–230.

Loehr, J. D., Kourtis, D., Vesper, C., Sebanz, N., & Knoblich, G. (2013). Monitoring individual and joint action outcomes in duet music performance. *Journal of Cognitive Neuroscience*, *25*(7), 1049–1061.

Macy, M. W., & Skvoretz, J. (1998). The Evolution of Trust and Cooperation between Strangers: A Computational Model. *American Sociological Review*, *63*(5), 638–660. https://doi.org/10.2307/2657332

Martínez-Íñigo, L., Engelhardt, A., Agil, M., Pilot, M., & Majolo, B. (2021). Intergroup lethal gang attacks in wild crested macaques, Macaca nigra. *Animal Behaviour*, *180*, 81–91.

McEllin, L., Fiedler, S., & Sebanz, N. (2022). *Partner Choice in Action*. https://doi.org/10.31234/osf.io/89ves

McEllin, L., Knoblich, G., & Sebanz, N. (2018). Distinct kinematic markers of demonstration and joint action coordination? Evidence from virtual xylophone playing. *Journal of Experimental Psychology: Human Perception and Performance*, *44*, 885–897. https://doi.org/10.1037/xhp0000505

McPhee, A., Manzone, J., & Welsh, T. (2016). Timmy, Lassie, Clyde, Daffy, Hedwig, and Polly: Joint attention effects between human and nonhuman animals. *Journal of Vision*, *16*(12), 1003–1003.

Michael, J. (2022). *The philosophy and psychology of commitment*. Taylor & Francis.

Michael, J., McEllin, L., & Felber, A. (2020). Prosocial effects of coordination – What, how and why? *Acta Psychologica*, *207*, 103083. https://doi.org/10.1016/j.actpsy.2020.103083

Michael, J., Sebanz, N., & Knoblich, G. (2016a). Observing joint action: Coordination creates commitment. *Cognition*, *157*, 106–113. https://doi.org/10.1016/j.cognition.2016.08.024

Michael, J., Sebanz, N., & Knoblich, G. (2016b). The Sense of Commitment: A Minimal Approach. *Frontiers in Psychology*, *6*.

Milner-Gulland, E. J., Fryxell, J. M., & Sinclair, A. R. (2011). *Animal migration: A synthesis*. OUP Oxford.

Miss, F. M., Adriaense, J. E. C., & Burkart, J. M. (2022). Towards integrating joint action research: Developmental and evolutionary perspectives on co-representation. *Neuroscience & Biobehavioral Reviews*, *143*, 104924. https://doi.org/10.1016/j.neubiorev.2022.104924

Molenberghs, P., Cunnington, R., & Mattingley, J. B. (2012). Brain regions with mirror properties: A meta-analysis of 125 human fMRI studies. *Neuroscience & Biobehavioral Reviews*, *36*(1), 341–349. https://doi.org/10.1016/j.neubiorev.2011.07.004

Moskowitz, J. B., Berger, S. A., Fooken, J., Castelhano, M. S., Gallivan, J. P., & Flanagan, J. R. (2023). The influence of movement-related costs when searching to act and acting to search. *Journal of Neurophysiology*, *129*(1), 115–130. https://doi.org/10.1152/jn.00305.2022

Mosteller, F., & Nogee, P. (1951). An Experimental Measurement of Utility. *Journal* *of Political Economy*, *59*(5), 371–404. https://www.jstor.org/stable/1825254

Nowak, M. A., & Sigmund, K. (2005). Evolution of indirect reciprocity. *Nature*, *437*(7063), 1291–1298. https://doi.org/10.1038/nature04131

O'Connor, C., & Joffe, H. (2020). Intercoder Reliability in Qualitative Research: Debates and Practical Guidelines. *International Journal of Qualitative Methods*, *19*, 1609406919899220. https://doi.org/10.1177/1609406919899220

Obhi, S. S., & Sebanz, N. (2011). Moving together: Toward understanding the mechanisms of joint action. *Experimental Brain Research*, *211*(3), 329–336. https://doi.org/10.1007/s00221-011-2721-0

Paulhus, D. L. (1998). Balanced inventory of desirable responding. *Journal of Personality and Social Psychology*.

Perc, M., & Szolnoki, A. (2008). Social diversity and promotion of cooperation in the spatial prisoner's dilemma game. *Physical Review E*, *77*(1), 011904. https://doi.org/10.1103/PhysRevE.77.011904

Pezzulo, G., Donnarumma, F., & Dindo, H. (2013). Human Sensorimotor Communication: A Theory of Signaling in Online Social Interactions. *PLOS ONE*, *8*(11), e79876. https://doi.org/10.1371/journal.pone.0079876

Pezzulo, G., Donnarumma, F., Dindo, H., D'Ausilio, A., Konvalinka, I., & Castelfranchi, C. (2019). The body talks: Sensorimotor communication and its brain and kinematic signatures. *Physics of Life Reviews*, *28*, 1–21. https://doi.org/10.1016/j.plrev.2018.06.014

R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Rangel, A., Camerer, C., & Montague, P. R. (2008). A framework for studying the neurobiology of value-based decision making. *Nature Reviews Neuroscience*, *9*(7), 545–556. https://doi.org/10.1038/nrn2357

Rekers, Y., Haun, D. B. M., & Tomasello, M. (2011). Children, but Not Chimpanzees, Prefer to Collaborate. *Current Biology*, *21*(20), 1756–1758. https://doi.org/10.101

6/j.cub.2011.08.066

Repacholi, B. M., & Gopnik, A. (1997). Early reasoning about desires: Evidence from 14-and 18-month-olds. *Developmental Psychology*, *33*(1), 12.

Rich, C., & Sidner, C. L. (1997). Segmented Interaction History in a Collaborative Interface Agent. *Proceedings of the 2nd International Conference on Intelligent User Interfaces*, 23–30. https://doi.org/10.1145/238218.238222

Richardson, D. C., Hoover, M. A., & Ghane, A. (2008). Joint perception: Gaze and the presence of others. *Proceedings of the Annual Meeting of the Cognitive Science Society*, *30*.

Rizzolatti, G., & Craighero, L. (2004). THE MIRROR-NEURON SYSTEM. *Annual Review of Neuroscience*, *27*(1), 169–192. https://doi.org/10.1146/annurev.neuro.27.070203.144230

Rizzolatti, G., Fadiga, L., Gallese, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research*, *3*(2), 131–141.

Rumble, A. C., Van Lange, P. A., & Parks, C. D. (2010). The benefits of empathy: When empathy may sustain cooperation in social dilemmas. *European Journal of Social Psychology*, *40*(5), 856–866.

Ruys, K. I., & Aarts, H. (2010). When competition merges people's behavior: Interdependency activates shared action representations. *Journal of Experimental Social Psychology*, *46*(6), 1130–1133. https://doi.org/10.1016/j.jesp.2010.05.016

Salimpour, Y., & Shadmehr, R. (2014). Motor costs and the coordination of the two arms. *Journal of Neuroscience*, *34*(5), 1806–1818.

Sandstrom, G. M. (2023). Even minimal student-instructor interactions may increase enjoyment in the classroom: Preliminary evidence that greeting your students may have benefits even if you can't remember their names. *Plos One*, *18*(8), e0288166.

Schevernels, H., Krebs, R. M., Santens, P., Woldorff, M. G., & Boehler, C. N. (2014). Task preparation processes related to reward prediction precede those related to task-difficulty expectation. *NeuroImage*, *84*, 639–647. https://doi.org/10.1016/j.neuroimage.2013.09.039

Schmidt, R. C., & Richardson, M. J. (2008). Dynamics of interpersonal coordination. *Coordination: Neural, Behavioral and Social Dynamics*, 281–308.

Schmitz, L., Vesper, C., Sebanz, N., & Knoblich, G. (2017). Co-representation of others' task constraints in joint action. *Journal of Experimental Psychology: Human Perception and Performance*, *43*(8), 1480.

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: Bodies and minds moving together. *Trends in Cognitive Sciences*, *10*(2), 70–76. https://doi.org/10.1016/j.tics.2005.12.009

Sebanz, N., & Knoblich, G. (2021). Progress in Joint-Action Research. *Current Directions in Psychological Science*, *30*(2), 138–143. https://doi.org/10.1177/0963721420984425

Sebanz, N., Knoblich, G., & Prinz, W. (2003). Representing others' actions: Just like one's own? *Cognition*, *88*(3), B11–B21.

Shadmehr, R., Huang, H. J., & Ahmed, A. A. (2016). A Representation of Effort in Decision-Making and Motor Control. *Current Biology*, *26*(14), 1929–1934. https://doi.org/10.1016/j.cub.2016.05.065

Shang, J., & Liu, Z. (2022). Vocal attractiveness matters: Social preferences in cooperative behavior. *Frontiers in Psychology*, *13*.

Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2012). A 21 word solution. *Available at SSRN 2160588*.

Simonsohn, U. (2015). Small Telescopes: Detectability and the Evaluation of Replication Results. *Psychological Science*, *26*(5), 559–569. https://doi.org/10.1177/0956797614567341

Skantze, G., Hjalmarsson, A., & Oertel, C. (2014). Turn-taking, feedback and joint attention in situated human–robot interaction. *Speech Communication*, *65*, 50–66.

Stocker, M., Loretto, M.-C., Sterck, E. H. M., Bugnyar, T., & Massen, J. J. M. (2020). Cooperation with closely bonded individuals reduces cortisol levels in long-tailed macaques. *Royal Society Open Science*, *7*(5), 191056. https://doi.org/10.1098/rsos.191056

Sussman, R. W., Garber, P. A., & Cheverud, J. M. (2005). Importance of cooperation and affiliation in the evolution of primate sociality. *American Journal of Physical Anthropology*, *128*(1), 84–97.

Székely, M., & Michael, J. (2023). In it together: Evidence of a preference for the fair distribution of effort in joint action. *Evolution and Human Behavior*, *44*(4), 339–348.

Todorov, E. (2004). Optimality principles in sensorimotor control. *Nature Neuroscience*, *7*(9), 907–915. https://doi.org/10.1038/nn1309

Tomasello, M. (1995). Joint attention as social cognition. *Joint Attention: Its Origins and Role in Development*, *103130*, 103–130.

Tomasello, M., Dweck, C., Silk, J., Skyrms, B., Spelke, E. S., & Spelke, E. S. (2009). *Why We Cooperate*. MIT Press.

Török, G., Pomiechowska, B., Csibra, G., & Sebanz, N. (2019). Rationality in joint action: Maximizing coefficiency in coordination. *Psychological Science*, *30*(6), 930–941.

Tversky, A. (1967). Additivity, utility, and subjective probability. *Journal of Mathematical Psychology*, *4*(2), 175–201.

Vaez-Alaei, M., Deniaud, I., Marmier, F., Gourc, D., & Cowan, R. (2022). A partner selection framework for strategic alliances based on project complexity and partner's past experience. *Enterprise Information Systems*, *16*(6), 1889038. https://doi.org/10.1080/17517575.2021.1889038

Van de Ven, A. H., Delbecq, A. L., & Koenig Jr, R. (1976). Determinants of coordination modes within organizations. *American Sociological Review*, 322–338.

van der Wel, R. P. R. D., Becchio, C., Curioni, A., & Wolf, T. (2021). Understanding joint action: Current theoretical and empirical approaches. *Acta Psychologica*, *215*, 103285. https://doi.org/10.1016/j.actpsy.2021.103285

van Schie, H. T., Mars, R. B., Coles, M. G. H., & Bekkering, H. (2004). Modulation of activity in medial frontal and motor cortices during error observation. *Nature Neuroscience*, *7*(5), 549–554. https://doi.org/10.1038/nn1239

Vesper, C., Abramova, E., Bütepage, J., Ciardo, F., Crossey, B., Effenberg, A., Hristova, D., Karlinsky, A., McEllin, L., Nijssen, S. R. R., Schmitz, L., & Wahn, B. (2017). Joint Action: Mental Representations, Shared Information and General Mechanisms for Coordinating with Others. *Frontiers in Psychology*, *7*.

Wesselmann, E. D., Cardoso, F. D., Slater, S., & Williams, K. D. (2012). To be looked at as though air: Civil attention matters. *Psychological Science*, *23*(2), 166–168.

West, S. A., Pen, I., & Griffin, A. S. (2002). Cooperation and Competition Between Relatives. *Science*, *296*(5565), 72–75. https://doi.org/10.1126/science.1065507

Wolf, T., Sebanz, N., & Knoblich, G. (2018). Joint action coordination in expert-novice pairs: Can experts predict novices' suboptimal timing? *Cognition*, *178*, 103–108. https://doi.org/10.1016/j.cognition.2018.05.012

Woźniak, M., & Knoblich, G. (2022). Communication and action predictability: Two complementary strategies for successful cooperation. *Royal Society Open Science*, *9*(9), 220577.

Wu, J., Balliet, D., & Van Lange, P. A. (2016). Reputation, gossip, and human cooperation. *Social and Personality Psychology Compass*, *10*(6), 350–364.

Zander, A., & Havelin, A. (1960). Social comparison and interpersonal attraction. *Human Relations*, *13*(1), 21–32.