Planning for a Joint Task Distribution: To be Fair and Timely

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Submitted to Central European University

Department of Cognitive Science

In partial fulfilment of the requirements for the degree of

Doctor of Philosophy in Cognitive Science

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Budapest, Hungary

2021

Declaration of Authorship

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no materials previously published or written by another person, or which have been accepted for the award of any other degree or diploma at Central European University or any other educational institution, except where due acknowledgment is made in the form of bibliographical reference.

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Abstract

From housework to small group projects to large-scale international ventures, humans often must plan how to divide a task such that partners coordinate effectively and fairly. While much research has focused on the processes that enable people to plan and perform a joint action, much less is known about how joint action partners specifically plan for and achieve a fair task distribution. One possible cognitive mechanism is mentalizing, where each partner thinks about what actions the other will perform. A further process that can help with task distribution is the use of heuristics like turn-taking, where partners follow a temporal order of actions to achieve a successful task distribution. Another related mechanism is the use of perceptual features in the task, where each partner responds to different features. Using a new experimental approach that included a measure of planning time, we investigated the role of these mechanisms in task distribution. In three empirical studies, we found that people planning for a (actual or imaginary) joint task distribution preferred relying on heuristics that impose a temporal order. Pairs using heuristics were able to minimize mentalizing and even planned faster than individuals using perceptual features for their task distributions. Additionally, when these heuristics that pairs preferred were fair procedures but led to an unequal distribution of effort between partners, planning becomes more difficult and took a longer time. Altogether, these findings suggest that while many hands can make light work, this is likely dependent on the applicability of fair and easy heuristics.

Acknowledgements

This dissertation would not have been possible without the support and invaluable assistance from my supervisors. Thank you, Dr. Günther Knoblich, for your trust and your patient guidance throughout the years. Thank you, Dr. Natalie Sebanz, for always listening, sharing, and providing many necessary perspectives throughout this project and beyond.

Thank you to all the people in the SOMBY Lab. I am especially grateful to Fruzsina Elekes, Anna Maria Lisincki, Fruzsina Kollányi, Vanda Derzsi, Dávid Csűrös, and Fanni Takátsy for helping me in the labs with data collection. Their assistance makes up a huge and vital part of this project. Thank you, very much.

Thank you to all the people at the Cognitive Science Department. I am most grateful to Györgyné Finta, Eszter Salamon, and Andrea Jenei for helping me not only with the administrative matters but also when I needed help beyond departmental matters. Thank you, thank you, and thank you.

To my friends and family, thank you for always being there for me when I got home. Thank you for reminding me always that I have got a home.

And lastly, to my dearest and most brilliant. Thank you.

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List of Abbreviations

AC	Action Constraint
ED	Effort Distribution
M	Mean
MC	Minimal Coordination
PF	Perceptual Feature
PT	Preview Time
RT	Reaction Time
SD	Standard Deviation
TD	Task Distribution
TT	Turn-taking

Introduction

From when to till the lands to what ingredients to gather to prepare for dinner, the ability to look ahead in time can set us at an advantage in many situations. Albeit commonly inaccurate even with the benefit of hindsight (Buehler, Griffin, & Peetz, 2010; Kahneman & Tversky, 1982), planning allows us to determine in advance the steps needed to achieve a desired outcome. Across human societies where cooperative interactions shape much of everyday life (Tomasello, 2009b), this means regularly coming up with plans that involves the collaborative effort of multiple individuals.

Sometimes, a joint action plan can benefit from having partners perform subtasks in a particular temporal order, such as one partner folding half of the huge laundry load first before leaving the remaining half to the other partner. Sometimes, such plans are determined by specifying what aspect of a task each partner is responsible for. In this case, this would be the use of a featural order and might involve one partner being responsible for folding away the children-sized laundry, and the other partner specialised in folding away the adult-sized clothes. Most of the times, though, people planning for a collaborative effort are likely to be more concerned with how to fairly distribute a task. Research has found that not only are humans strongly motivated to be fair and altruistic (Fehr & Fischbacher, 2003; Fehr & Schmidt, 2006), but that they also display an intuitive preference for cooperative behaviour (Rand, 2016; Rand et al., 2014). It would appear to begin from a young age too. Children have been found to prefer a fair procedure over one that would otherwise unfairly reward them at the expense of others (Grocke, Rossano, & Tomasello, 2019).

Often, verbal communication between partners can form a vital part of planning for joint action. Prior to assembling a toy model together, for example, group members discussed and explicitly strategized a division of labour that had different members be responsible for different components of the task (Raveendran, Puranam, & Warglien, 2016). Most of the time though, coordination can happen tacitly and without any explicit discussions of strategies or of who does what and when. Be it coordinating to lift a long wooden plank together (Isenhower, Richardson, Carello, Baron, & Marsh, 2010), improvising movements to be mirrored (Noy, Dekel, & Alon, 2011), engaging in a visual search together (Brennan, Chen, Dickinson, Neider, & Zelinsky, 2008), or engaging in collective recall (Wegner, Erber, & Raymond, 1991), partners have found ways to coordinate successfully without needing to verbally communicate what they were planning to do. Additionally, as Wittenbaum and colleagues (1996) find, tacit coordination can happen outside of a person's awareness such that a person cannot accurately report the strategy they had taken in order to coordinate with their group members on the joint task.

Naturally, with the diversity of social settings in this world, there are many ways that can help facilitate a fair task distribution between partners. Needing to plan for a joint task distribution then, what would be the approach one imagines best for the situation? What might the cognitive processes involved be when people jointly plan for a fair task distribution between partners? To start, we look closer at the two broad approaches available for planning a fair task distribution. One approach would be to impose a temporal order, such that partners complete a part of the task, one at a time. The other approach would be to use a featural order, where the task is divvied up according to its features that different partners will each focus on separately.

Temporal Order of Actions

One planning approach for a fair task distribution is to focus simply on the temporal aspects of the coordination. This approach would rely on strategies where a temporal order specifies who responds when in a sequence of actions. One such strategy is turn-taking, a mechanism that regulates coordination in a joint task where only one individual may act or benefit at any one time (Lau & Mui, 2008; Melis, Grocke, Kalbitz, & Tomasello, 2016; Neill, 2003). From distributing speaking time across cultures (Stivers et al., 2009), regulating access to prime fishing spots (Berkes, 1986), to ensuring a fair distribution of obligations over time (Leo, 2017), turn-taking has been observed across a wide variety of situations. Infants too, have been found capable of proto-conversations with their caretakers, suggesting that humans are naturally predisposed to engage in turn-taking (Levinson, 2016). Planning to coordinate with a partner via turn-taking would be a fairly straightforward process, one that requires little mental effort except to specify who goes first (Helbing, Schönhof, Stark, & Holyst, 2005; Lau & Mui, 2012). There are limitations to turn-taking, however. From possession of public to private information about payoff structures (Kaplan & Ruffle, 2012), to differing costs of contribution between partners (Riyanto & Roy, 2019), there are often asymmetries inherent in a social context that can discourage the use of turn-taking.

Another strategy that could be used to define a temporal order in task distribution is minimal coordination, a heuristic related to the human bias to minimize energy costs in motor behaviour where possible (Lyons, Hansen, Hurding, & Elliott, 2006; Oliveira, Elliott, & Goodman, 2005). In the case of distributing a task, minimal coordination is the strategy of distributing a joint task in a way such that the number of coordination points (turns) between partners is minimized. In tasks with multiple sequential steps and for two partners, where the number of steps required is known in advance, one person could perform the first half of steps in the sequence and the other person could perform the second half of steps. This would not only ensure a fair task distribution on average, but also minimize potential coordination problems between the two partners that would otherwise imply additional costs for performing the joint action. The use of minimal coordination here is also not unlike the use of an 'equal division rule' to distribute resources, where the total pool of resources was simply divided equally among all the partners involved (Allison & Messick, 1990). Implementation of this equal division heuristic was not only easy but also led to a fair outcome for everyone involved (van Dijk & Wilke, 1996). Using minimal coordination to impose a temporal order, however, risks the chance of one partner facing a substantial loss in the event where having fulfilled her half, the other partner is unable to complete the other half. Often, at this point, the task would either be aborted or completed as an individual task.

Featural Order of Actions

Another approach to planning a task distribution is to focus more on the features of the task and on how each partner can rely on particular features for achieving a task distribution. One strategy is to focus on the simpler level of perceptual features when planning a task distribution. Within an environment, there often exist perceptual features that can be used to coordinate actions between individuals. Saliency (Schelling, 1980), in particular, would be a useful aspect by which perceptual features can be used to support coordination. For example, when asked to coordinate on a series of abstract diagrammatic questions such that their answers will be the same as their anonymous partners', participants made particularly salient features of each diagrams their focal point of coordination (Mehta, Starmer, & Sugden, 1994). Five-year-old children too, were able to use saliency as focal points for coordination (Grueneisen, Wyman, & Tomasello, 2015). In this study, pairs of children who could neither see nor communicate with each other were able to choose the same option out of four equivalent choices at above chance level.

Alternatively, one could also focus on the intermediary objects that could be independently generated in the task. This is a strategy that partners commonly use with tasks that are novel, nonrepetitive, and highly decomposable (Raveendran et al., 2016). In this case, planning to assemble a toy model together involved focusing on the component parts like battery and wheels, and assigning them each to different partners in the group.

Use of features as a task distribution strategy, however, is highly dependent on mutual knowledge of who will be responding to what (Clark, 1996). In the cases where salient perceptual features are used, partners coordinating on a joint task would need to be sure that what is considered salient is relative to a standard that is mutually recognised by all involved. While there may be some cases where a particular feature stands out immediately, oftentimes, there are multiple perceptual dimensions that can be used as a feature for coordination. Accordingly, use of a featural order can become quite difficult in task distributions, especially when perceptual features are ambiguous.

Fairness of It All

While cooperating fairly appears to be a default behaviour (Rand, 2016; Rand et al., 2014), fairness and cooperation in studies addressing this topic have been mostly based on decisions made about resources in economic games. Fairness outside of these games can be more than simply deriving the arithmetic half of one's personal endowment. In organizational justice research, two concepts of fairness are particularly relevant to how a task is distributed between partners. These two concepts are 'distributive fairness' and 'procedural fairness'. Distributive fairness is based on the perceived fairness of outcomes, and can be determined by various rules such as equity, equality, or need (Deutsch, 1975). In terms of equity, for example, fairness will be determined by the proportion of a person's contribution in relation to the amount of rewards and costs they incur. In terms of need, fairness will be distributing the resources according to who needs them more. In terms of equality, fairness will be an equal distribution of outcomes, disregarding a person's contribution or needs. Regardless of which rule, distributive fairness is most relevant to task distribution, especially when it comes to distributing tasks that are commonly unappealing, such as household chores (Frisco & Williams, 2003; Thomson, 2007). As a study on dual-income households in the United States finds, how housework is distributed between wife and husband can be a source of great unhappiness in the marriage (Frisco & Williams, 2003).

Procedural justice, on the other hand, is based on the perceived fairness of procedure (Cohen-Charash & Spector, 2001; Folger & Konovsky, 1989) and can refer to a process that is designed to ensure fair representation of all parties involved in the matter (Leventhal, 1980). Recent studies have found that children as young as three years old can recognize and choose a fair procedure over one that would otherwise privilege them at the expense of others (Grocke et al., 2019). Additionally, when the only procedure available was a partial one, eight-year-olds preferred throwing an additional resource away rather than using the partial procedure to assign it to one partner only (Shaw & Olson, 2014).

Procedural fairness, however, does not appear to be the only aspect of fairness that children are sensitive to. Indeed, when offered an unequal distribution of resources, four to seven-year-olds rejected a distribution where they were personally at a disadvantage while eight-year-olds rejected a distribution where they were personally at an advantage (Blake & McAuliffe, 2011). Three and five-year-old children too, while capable of choosing a fair procedure over a biased one, were less likely to give up a distribution where they were personally at an advantage (Grocke et al., 2019). This was even if accepting a more equal distribution meant that they still had the most rewards compared to their peers, albeit in a smaller amount than before.

Additionally, it would seem that not all fair procedures are valued similarly. A fair procedure was considered by adults to be most important in social settings where an interpersonal relationship is highly valued but also unstable (Barrett-Howard & Tyler, 1986). This include workplace settings, where fairness is recognised as important to maintaining positive collegial relationships, but difficult to achieve without the use fair procedures. The use of a veritable fair procedure such as a coin toss, however, appears to be restricted only to matters with unimportant outcomes (Keren & Teigen, 2010). In planning for a fair task distribution then, what procedure is used, and the fairness of the resulting distribution are clearly important factors to consider. A fair procedure can lead to a fair distribution, but a fair distribution may not necessarily be the result of a fair procedure (Cook & Hegtvedt, 1983).

Examining the Planning Process

Between focusing on how to achieve a fair task distribution, the temporal aspects of the task coordination, and the many task features that can serve as focal points for a task distribution, how partners jointly plan for a task distribution would appear to be a formidable task. Indeed, planning to work together often involves not only coordinating actions, but making inferences about others' intentions, and goals (Bratman, 1993). This ability to make inferences about others has been termed mentalizing (Apperly & Butterfill, 2009; U. Frith & Frith, 2003; Lombardo et al., 2010). While considered important for understanding the perspective of others and for predicting their actions (Amodio & Frith, 2006; C. D. Frith & Frith, 2006a; Spiers & Maguire, 2006), mentalizing has its limitations (Keysar, Lin, & Barr, 2003). For example, people may be able to understand how exactly perspectives are different but not necessarily act on them accordingly.

How can joint action planning processes be studied? One way to examine the planning processes for a fair task distribution is to make inferences retrospectively from the performance of the joint task. However, things hardly ever go as planned (Kahneman & Tversky, 1982; Pinto, 2013). Assessing how a joint task was performed would likely tell us more about the plans that were revised via mechanisms during online performance (Schilbach, 2014), such as mutual adaptation (Keller, Novembre, & Hove, 2014) or monitoring (Loehr, Kourtis, Vesper, Sebanz, & Knoblich, 2013), than of the initial plan that was thought as best during the planning process. Importantly, participants may not even be able to report accurately on the strategy they had actually taken to coordinate successfully with their group members (Wittenbaum et al., 1996). Another way to access the mental contents of a plan would be to use thought-listing, a method where participants simply list out all the thoughts that they had while planning for the task (Buehler, Griffin, & Ross, 1994; Peetz, Buehler, & Wilson, 2010). This technique, however, risks introducing measurement reactivity, especially in tasks with high cognitive demand, where the thoughts reported are more in reaction to the listing procedure than a part of the planning process (Cacioppo, Von Hippel, & Ernst, 1997).

Two new ways to examine the planning processes involved in generating a fair task distribution are proposed. The first is to use a planning time measure as a proxy for how much mentalizing was involved in the planning stage. Generally, planning for a fair task distribution between partners should be more difficult and take longer than planning for an equal task distribution within an individual (e.g., ensuring both hands or legs have the same energy expenditure). Partners would need to explicitly think about action plans that specify the actions of self in relation to the actions of other in order to predict and effectively carry out the joint action. In contrast, individuals planning a task distribution for both hands or legs need only think about their own actions. The length of planning time would then be indicative of how much mental effort was required for planning a fair task distribution.

A second way proposed to examine the planning process for a joint task is to ask individuals to plan and perform an imagined 'joint task'. In this case, an individual would plan for a joint task distribution and perform all the planned actions as both partners. This is on the assumption that without the chance of potential obstacles actually happening during the joint task, everything goes as planned in the imaginary joint mode. The performance measures obtained through this manner would not only reflect the strategy that people imagined best for the joint task, but also reveal what the preferred planning approach for a joint task is for most people. Additionally, by comparing performance in the imaginary joint condition to the actual joint performance, we would be able to examine how closely planning a joint task in an imaginary joint mode is related to planning an actual joint task.

Based on these new approaches to examine the cognitive processes involved in planning a fair task distribution, new experimental tasks were designed that allowed for a measure of planning time and the use of an imaginary joint condition. These new experimental tasks also allowed us to assess whether a temporal order or a featural order was used to achieve a fair task distribution. Most importantly, these tasks provided us with a way to diagnose whether a fair task distribution was achieved or not. Put together, the use of these new experimental tasks enabled us to get a comprehensive picture of the task distribution process, starting with the difficulty of planning a task distribution to whether a successful task distribution was eventually achieved and what approach was taken to arrive at a fair task distribution.

Preview of Studies

For many tasks in everyday life, there is often a sequence of actions to take to complete them successfully. Crucially, for many of these tasks, there is also often more than one way to complete them. Generally, the more alternatives there are to consider, the longer the time needed to come up with a task distribution plan. When planning to distribute such a task between two hands, individuals would naturally require some time in trying to figure out what the best approach is.

When planning for a fair task distribution between two partners, however, individuals would additionally need to ensure that each partner acts in a way that no one overlaps or does more or less than the other. This could take a long time when planning, possibly longer than individuals planning a task distribution for their own two hands. While pairs need to consider the various possible actions that each partner will take, individuals need only decide what the best course of action is for themselves.

Planning can be made easier for pairs, however, especially with the use of a temporal order or a featural order. If using either turn-taking or minimal coordination heuristics, partners would simply need to specify who takes the first turn. For example, using minimal coordination on a task comprising eight sequential subtasks would only require partners to know who will be acting on the first four subtasks to figure out who will be responsible for the last four subtasks. If using perceptual features, all that is required is consensus on who responds to what features of the task. In the case of a task comprised of red and green subtasks, for example, pairs can agree that one partner is responsible for acting on the red subtasks while the other is responsible for the green subtasks. It is thus an open question which strategies are involved when pairs plan for a joint task distribution, and what the cognitive processes underlying the use of particular strategies are. Addressing this question is the primary aim of this thesis.

Through three empirical studies, we tracked how three candidate cognitive processes are used when people plan for a fair task distribution. These three candidate processes are mentalizing, use of heuristics, and use of perceptual features. To test if mentalizing was used when planning for a task distribution, we compared the planning times of individuals and pairs. If mentalizing was used, partners needing to account for each other's actions in their task distribution plans should take a longer planning time than individuals who need only decide for themselves. To find out if heuristics were used, we examined when and how many times pairs switched turns between partners in a task sequence. If a minimal coordination heuristic was used, pairs should switch only once, even if they encounter long task sequences. If a turn-taking heuristic was used, partners should take turns after every subtask.

To test if perceptual features were used in planning a task distribution, we examined if pairs switched between partners according to how perceptual features in the task sequence switched. If perceptual features were used, every switch in relevant perceptual features should be accompanied by a switch in partners. For instance, a task that switches perceptual features every two subtasks should result in pairs switching turns between partners after every two subtasks too.

Study 1: Cognitive Mechanisms of Task Distribution

The first study comprised three experiments where we systematically tested our hypotheses regarding the three candidate mechanisms in the task distribution process. In the first experiment, to test for mentalizing, we compared the planning time individuals take to distribute a task between their two hands versus the planning time pairs take to distribute a task between partners. As a second test of mentalizing, we manipulated the mappings between stimuli and responses such that they were either ambiguous or unique. When mappings between stimuli and responses were unique, one item mapped to one correct response. When mappings between stimuli and responses were ambiguous, one item mapped to two correct responses. We hypothesized that task partners would perceive these ambiguous mappings to pose additional coordination problems that have to be solved by reasoning about which response a partner will make. Accordingly, planning for a task with ambiguous mappings should be more difficult and take longer than when mappings of stimuli and responses are unique. Individuals distributing a task between their two hands, however, need only decide which response to take. In this case, ambiguity in the stimuli and response mappings should have little to no impact on their task distribution process.

To test for use of perceptual features, we manipulated the task sequence such that the perceptual features distinguishing the subtasks either alternated by one, alternated by two, or alternated by four. If perceptual features were used, how partners switched turns should follow the alternation of perceptual features. Alternatively, if heuristics were used, then pairs should disregard how perceptual features switch in a task and instead, switch turns between partners after every item according to turn-taking or minimize the number of turns between partners as according to minimal coordination.

In the second experiment, we examined in more detail how the use of heuristics shapes the task distribution process. This is especially relevant since the first experiment demonstrated that pairs were using minimal coordination and turn-taking to achieve fair task distributions while individuals relied more on the perceptual features of the task. As use of these heuristics meant relying on a temporal order that simplified individual decisions, we asked if this could lead to pairs being more effective than individuals in achieving fair task distributions. To investigate this further, we used task sequences where perceptual features either supported turn-taking or minimal coordination, or both heuristics at the same time. This meant manipulating the rates by which perceptual features of the subtasks alternated. In a task sequence comprising eight subtasks, perceptual features of the subtasks that alternated by one supported turn-taking while perceptual features that alternated by four support minimal coordination. Where task sequences supported both turn-taking and minimal coordination at the same time, perceptual features of the subtasks were split into two sets that alternated at a different rate from each other. In this case, the colour feature of the subtasks may alternate by one while the form feature of the subtasks may alternate by four, and vice versa. If perceptual features were used to distribute a task, task sequences with perceptual features that alternate synchronously and uniquely would be easier to plan for than task sequences with perceptual features that alternate ambiguously at different rates. For the latter, there will be a need to consider and select which set of perceptual features to follow for task distribution. However, if heuristics were used to distribute a task, then sequences with perceptual features that alternate ambiguously should not pose any difficulty. Which set of perceptual features to follow would be easily determined by the choice of heuristics.

Oftentimes, the tasks we encounter in a group would require us to not only keep track of how often each partner responds, but also how often they perform a specific task. In the third experiment, we investigated how such additional constraints on actions affect the three mechanisms of mentalizing, use of heuristics, and use of perceptual features in a task distribution. If implementing the additional constraints on the type of actions required in a task distribution enhanced the need for mentalizing, we should see a longer planning time. Pairs would need to ensure that each partner makes a certain type of action for a certain number of times in order to achieve a fair task distribution. However, if mentalizing could be minimized by use of heuristics or perceptual features, we expect to see more use of turn-taking, minimal coordination, or perceptual features in task distributions. Use of these latter mechanisms would mean relying on a temporal order or a featural order of actions, either of which would help provide a quick and easy approach to task distribution.

Study 2: Procedural and Distributive Fairness in Task Distribution

In the second study, as a first test of understanding how procedural and distributive fairness affect task distribution planning, we asked how important distributive fairness is for the use of a fair procedure in task distribution. To do this, we set up experimental tasks where pairs can achieve procedural fairness but not distributive fairness. Importantly, while most studies of fairness have examined how resources are distributed between people, we were interested in the task distribution process where people distribute chores and labour between themselves. In this case, while a fair procedure could be used to achieve a successful task distribution, the resulting distribution of effort between partners may not be equal or fair. In the context of this study, this also meant that while the turn-taking and minimal coordination heuristics were fair procedures that pairs could use to achieve a successful task distribution, these procedures did not necessarily lead to distributive fairness of effort between partners.

In the first experiment of this second study, we manipulated the items in the task such that some items required a bigger response effort than others. Additionally, we designed task sequences such that by using fair procedures like turn-taking or minimal coordination, one partner would have put in more effort into the task than the other. If distributive fairness is not an important concern when planning to use a fair procedure for a task distribution, fair procedures like turn-taking or minimal coordination should still be used even if they lead to an unequal distribution of effort between partners. If distributive fairness is important and guides the use of a fair procedure in task distribution, however, only strategies that ensure an equal distribution of effort between partners should be used.

In the second experiment, we tested the importance of distributive fairness further by pitting the two fair procedures of turn-taking and minimal coordination heuristics against each other. To do this, we designed task sequences that led to an equal distribution of effort by use of minimal coordination but not of turn-taking. If distributive fairness is important and guides the use of a fair procedure in task distribution, minimal coordination should be used more often than turn-taking. If distributive fairness is not an important concern when planning to use a fair procedure for a task distribution, turn-taking should still be used even if it leads to an unequal distribution of effort between partners.

Study 3: Task Distribution in the Imaginary Joint Mode

In the third and last study, we tested whether the patterns of task distribution obtained in the previous studies could be reproduced with our new imaginary joint action method. First, we wanted to know if planning a task distribution in the imaginary joint mode was comparable to planning an actual joint task distribution. To do this, we repeated the first experiment from the first study but with individuals who planned and performed a task distribution in individual or imaginary joint mode. To recall, the very first experiment was performed as a first test of the three cognitive mechanisms of mentalizing, use of perceptual features, and use of heuristics in task distribution. It was adapted to also serve as a good first test for the new imaginary joint action method. This meant having individuals imagine that their left and right hands were one partner each and performing the task distribution such that each partner responded equally often. Given that the imaginary joint condition and the individual condition did not differ in terms of actual performance requirements, any differences that we observe between these two conditions can be attributed to the imaginary joint mode of the task distribution. Alternatively, if planning for a fair task distribution in the imaginary joint condition is no different from planning in the individual condition or if the joint mode is not easily imagined, there should be no differences in task distribution between the two conditions.

The next experiment in Study 3 is taken from the Study 2 where we investigated how procedural fairness and distributive fairness affect the task distribution process. Applying the imaginary joint action method to this experiment (Study 2 Experiment 2) meant being able to find out how distributive fairness affects the use of a fair procedure when people plan for and perform a joint task distribution as two partners. If distributive fairness has no bearing on the use of a fair procedure in the imaginary joint mode, fair procedures like turn-taking or minimal coordination should still be used in the imaginary joint condition even if they do not lead to distributive fairness. Alternatively, if achieving distributive fairness is important in the imaginary joint mode, only strategies that ensure an equal distribution of effort between partners should be used. Any difference that we observe in this experiment between the imaginary joint condition and the actual joint condition would also help to better illuminate the impact of fairness on the task distribution process.

In the following three chapters, I report and discuss the results of each empirical study in detail. In the last chapter of this thesis, I discuss the findings from all three empirical studies. Specifically, I discuss them in terms of how a temporal order or a featural order contributes to the task distribution process. I also consider how the two new methods developed to access the planning process fare across the different experiments and how they can be further incorporated into future experiments to better understand the cognitive processes that are involved in planning a fair task distribution.

Chapter 1: The Role of Mentalizing, Social Heuristics, and Perceptual Task Features

The ability to engage in joint actions is a defining feature of human culture (Tomasello, 2009a). Previous research has addressed important components of this ability. Research on shared intentionality (Tomasello & Carpenter, 2007) has established that human infants and toddlers have an ability to share intentions that is absent in other species (Herrmann, Call, Hernández-Lloreda, Hare, & Tomasello, 2007). Research on the motivational factors favouring cooperation and joint action has established that humans display an ‘irrational’ tendency to be fair and altruistic (Fehr & Fischbacher, 2003; Fehr & Schmidt, 2006) and feel commitments to go through with joint actions against their self-interests (Gilbert, 2006; Michael, Sebanz, & Knoblich, 2016; Székely & Michael, 2018). Research on the psychological mechanisms enabling joint actions has revealed how partners represent and predict each other’s actions (della Gatta et al., 2017; Sebanz & Knoblich, 2009), how they coordinate with one another (Keller et al., 2014; Knoblich, Butterfill, & Sebanz, 2011; Schmidt & Richardson, 2008), and how they monitor joint performances (Loehr et al., 2013).

An important question that builds on the different research lines above is what are the cognitive processes that enable joint action partners to plan a fair task distribution in advance of acting together. Despite its broad relevance, this question has not received much attention in previous research. An exception are studies on language use (Brennan, Galati, & Kuhlen, 2010; Clark, 1996; Dale, Fusaroli, Duran, & Richardson, 2014) providing indications that verbal communication can provide much of the common ground needed to ensure fair planning. Verbal communication, however, may not always be helpful or needed when planning to coordinate with others on a joint task. Even knowing exactly what someone was asking for was not enough to prompt adults to correctly reach for the referred object (Keysar et al., 2003). Additionally, coordination can often occur tacitly without verbal communication

(Brennan et al., 2008; Noy et al., 2011; Schelling, 1980; Wegner et al., 1991; Wittenbaum et al., 1996) and without explicit discussion of what strategy to use (Isenhower et al., 2010). One common way by which partners can coordinate successfully and without communicating would be to consider fairness and let what constitutes a fair task distribution guide their actions (Schelling, 1980; van Dijk & Wilke, 1996). Some theorists have also argued that assessing the fairness of a person or authority can serve as an important heuristic to manage the uncertainty of whether said person or authority can be trusted or not (van den Bos, Lind, & Wilke, 2001).

What then, constitutes a fair task distribution? Previous studies have relied very much on economic games to understand how and when people make fair decisions (Capraro, 2019; Fehr & Schmidt, 1999, 2006). Allocating resources fairly between partners in particular, have been found to be a driven strongly by intuition rather than deliberate thinking (Rand, 2016; Rand et al., 2014). Not all joint tasks involve a distribution of resources, however. Nor can fairness always be conveniently and arithmetically derived. Some joint tasks common in everyday life include household chores, where children preferred an equal distribution among siblings (Thomson, 2007), and where wives and husbands can have different perceptions of what is considered a fair share of the housework (Frisco & Williams, 2003).

In the present study, our goal was to identify processes that enable co-actors to achieve fair task distributions before engaging in joint action, and without communicating verbally. We limit our tasks to those that do not involve resources or rewards, and where a fair task distribution would clearly be a fair distribution of effort. We addressed three cognitive processes that might be involved when planning a fair task distribution. These processes include reasoning about what a partner will do, using task distribution heuristics, and basing the task distribution on perceptual task features. In the following, we will discuss each of these three candidate processes in more detail, and then report three experiments that investigated which processes enable joint action partners to achieve fair task distributions.

Mentalizing in Task Distribution

When coordinating with another person to perform a joint action, there is often a need to coordinate explicit higher-level goals. Apart from understanding others' perceptions and goals (Carpenter, Nagell, & Tomasello, 1998), coordinating at this higher level may require conceiving of others as agents whose mental states of beliefs and desires are important motivators for their actions. The ability to reason and to make inferences about others at this level has been studied in research addressing theory of mind, often also referred to as mentalizing (Apperly & Butterfill, 2009; U. Frith & Frith, 2003; Lombardo et al., 2010). Mentalizing refers to the ability to attribute mental states to others and is considered important to understanding the perspective of others and in predicting their actions (Amodio & Frith, 2006; C. D. Frith & Frith, 2006a; Spiers & Maguire, 2006).

As a form of abstract inferential process, mentalizing relates closely to the sophisticated high-level intentional structure which philosophers often view as a central precondition for successfully performing joint actions (Tollefsen & Dale, 2012). Most notably, Bratman (1993) postulated that for a joint action to happen, there has to be an intention to jointly work together. Importantly, this intention to work together must be mutual and shared between the parties involved. Shared intention requires that action plans from the involved individuals mesh and cohere together for there to be any joint action. By such an account, planning a fair task distribution with another person would at least necessitate inferring and attributing mental states to the other person and reasoning about these mental states in ways that can help to improve and facilitate joint action. However, recent joint action research suggests that mentalizing may not always be as involved when planning for a fair task distribution (Brennan et al., 2008; Isenhower et al., 2010). For example, partners on a collaborative search task performed better simply knowing where the other was looking at than when they were also allowed to talk to each other (Brennan et al., 2008). This would suggest that there are ways by which coordination can happen tacitly and easily, without needing much prior discussion or reasoning of action plans.

Perceptual Features in Task Distribution

One shortcut to achieving a fair task distribution may consist in using perceptual task features to coordinate. For instance, if a joint task consists in sorting two kinds of objects, such as green apples and oranges, then colour could be used to achieve a task distribution that will be fair as long as an equal number of objects of both kinds are present, and lifting the two kinds of objects requires the same individual effort.

The perhaps most famous examples for how partners may achieve coordination using salient features of an environment or a task comes from the work of Schelling (1980), who claimed that highly salient focal points are particularly useful in coordination when communication is difficult or absent. For instance, the highest structure in a city (e.g., the Eiffel tower in Paris) is a salient feature that would enable two strangers, who know nothing about one another, to meet. When Mehta and colleagues (1994), asked participants to coordinate on a series of abstract questions using pen and paper, such that their answers will be the same as their anonymous partners', they made particularly salient features of the questions their point of coordination. Thus, it appears that salient features can help reduce the ambiguity that arises from not knowing what one's partner is planning to do, especially in cases where no open channels of communication are available. In Schelling coordination games, saliency is not purely perceptual but also depends on common knowledge (for most people, the Eiffel tower is the first building that comes to mind when thinking about Paris). However, salient perceptual features may be sufficient in some tasks, as when jointly sorting objects that differ on a perceptual dimension such as form and/or colour.

Heuristics in Task Distribution

The third way by which fair task distributions can be achieved is via use of heuristics. Heuristics are rule-of-thumb, practical behaviours that can simplify individual decisions (Tversky & Kahneman, 1974), aid problem solving (Newell & Simon, 1972), facilitate interactions (Rand et al., 2014), and smooth workflow (Gigerenzer, 2006).

The Social Heuristics Hypothesis by Rand and colleagues (2016; 2014) provides a starting point for asking how heuristics may be used to achieve fair task distributions. Analysing decisions in economic games according to the time constraints implied, Rand and colleagues (2016; 2013; 2014) found that cooperative behaviour was more frequent under time pressure, suggesting an automatic preference for cooperation. When there was more time to deliberate, individuals acted more in accordance with their own interests rather than maximizing the overall welfare of all players. Døssing, Piovesan, and Wengström (2017) found that people playing the public goods game under a high cognitive load contributed on average half of their initial endowment to the public good. By contrast, those playing under a low cognitive load only contributed an average of 30% of their endowment.

This supports Rand and colleagues' (2016; 2014) claim that people learn and internalize what is successful in societies where cooperation is advantageous. Cooperation becomes automatic and the first instinctive response to social situations. Further deliberation is then required to think about how to maximize one's own individual benefits. The Social Heuristics Hypothesis, however, is based mostly on results from economic games that invoke a single decision about cooperation. Many successful joint actions often require more than a single decision of whether to cooperate or not. To have decided to cooperate is one thing. To plan and follow up on this decision and to flesh out how to cooperate, e.g., coming up with a fair task distribution, is another. This is especially true for tasks such as housework (Frisco &

Williams, 2003) or group projects (Aggarwal & O'Brien, 2008), where cooperation is necessary across multiple sequential steps or over a period of time.

One powerful and general heuristic that can be used to achieve such fair task distributions is turn-taking. Turn-taking is common in everyday life interactions, chief of which is minimizing overlap between speakers in a conversation. As Levinson (2016) suggests, humans appear to be naturally predisposed to engage in turn-taking. Infants are already able to take turns and to participate in proto-conversations with their caretakers. Analysis of conversation samples in 10 different languages also find that there are enough regularities to suggest that turn-taking is a universal interactional system (Stivers et al., 2009). With turn-taking, planning a joint action would simply require knowing when your turn is. Considering that turn-taking is fairly ubiquitous, planning a joint task distribution with turn-taking could be fairly straightforward, especially if the task consists of multiple sequential steps or occurs over a period of time. In this case, turn-taking would also ensure a fair task distribution, on average, even if individual task steps vary in the amount of individual effort they require.

A second heuristic joint action partners may use is to minimise the number of coordination points that are required to achieve a fair task distribution. This is a heuristic related to the human bias to minimize energy costs in motor behaviour where possible (Lyons et al., 2006; Oliveira et al., 2005) and not unlike the 'equal division rule' where the total resources is simply divided equally among all the partners involved (Allison & Messick, 1990). Similarly, such a heuristic would work best when the joint task involves multiple sequential steps. If the number of steps required is known in advance for two partners, for example, then one person could perform the first half of steps in the sequence and the other person could perform the second half of steps in the sequence. This would not only ensure a fair task distribution, on average, but also minimize potential coordination problems between the two partners that would otherwise imply additional costs for performing the joint action.

Both turn-taking and minimal coordination heuristics appear to be rooted in facilitating human interactions and smoothing workflow in social contexts. There is, however, an open question as to whether these heuristics are specific to task distribution in social contexts or whether they are general-purpose heuristics applied to both social and non-social contexts. For instance, turn-taking and minimal coordination heuristics may also be used to distribute the effort in an individual multi-step task equally between the two hands of one person. One example would be the task of picking strawberries. One could alternate hands each time or switch hands only when about half of the strawberries in the patch have been picked. Thus, if the same heuristics were used to distribute tasks within and across individuals, this would imply that the heuristics used are not genuinely dedicated to social situations but of a more general nature.

The Present Study

Mentalizing, use of perceptual features, and use of heuristics are three mechanisms by which people can fairly distribute and coordinate on a joint task. To examine which of these mechanisms are involved in planning fair task distributions, we designed a new experimental task that appropriates the various multi-step tasks we encounter in everyday life. Pairs of participants were asked to perform a sequence of eight choice reactions in response to a sequence of eight items. This sequence of eight items was first presented in a preview before the task was performed. In the joint condition, participants were instructed to ensure that each person responded equally often. In the individual condition, participants were instructed to ensure that they responded equally often with each hand. After the preview, participants responded as fast as possible to the eight individual items sequentially presented. The task provides direct measures of: (1) planning time defined as the time taken to preview the whole sequence; (2) reaction times and errors for each item in the sequence as performance measures; and (3) patterns of task distribution as a measure for use of heuristics.

General Predictions

If mentalizing is used to arrive at fair task distributions, planning should be more difficult for pairs than for individuals. Pairs would need to explicitly think about action plans that specify the actions of self and other and their relation in order to predict and effectively carry out the joint action. If mentalizing is used, this mental accounting of who is responsible for different parts of the tasks should lead pairs to take a longer planning time than individuals who need only to account for themselves in a task distribution. Mentalizing should also result in higher RTs during joint task performance due to monitoring whether task progress is as planned.

If heuristics are used to arrive at a fair task distribution between individuals, no differences in planning time and RTs during task performance are expected between the individual and joint condition. If general heuristics are used to plan a task distribution, they should be used alike during joint and individual performance. If these heuristics are used more in the joint condition than in the individual condition, this would indicate that they are dedicated to being used in social contexts. We will address two specific heuristics, turn taking and minimal coordination. Take a sequence with eight subtasks as an example. If two players, Player 1 (P1) and Player 2 (P2) apply the turn-taking heuristic, they should reliably produce one of the following patterns: P1-P2-P1-P2-P1-P2-P1-P2 or P2-P1-P2-P1-P2-P1-P2-P1. If they apply the minimal coordination heuristic, they should produce one of the following patterns: P1-P1-P1-P1-P2-P2-P2-P2 or P2-P2-P2-P2-P1-P1-P1-P1.

If perceptual features of the task are used to arrive at a fair task distribution, the distribution should follow the perceptual characteristics that can be used to distinguish different types of items that require an action. Mentalizing then, could be minimized as task distribution could easily follow perceptual features that are adequate to separate task items into two different types. Planning a task distribution should thus be easier and faster when perceptual features support a specific task distribution. Alternatively, if perceptual features of the task support the use of task distribution heuristics, task distribution should follow perceptual characteristics that support the use of particular heuristics (e.g., alternating perceptual features for the turn-taking heuristic). Planning a task distribution would thus be easier and faster when perceptual features support use of heuristics.

One way to determine whether perceptual features directly guide task distribution or whether they support heuristics is to distribute items with distinguishable perceptual features across the sequence in a way that does not support heuristics use (i.e., features do not alternate or switch in the middle of the sequence). If heuristics use is key to achieving fair task distributions, they should still be used. If perceptual features are key, task distribution should follow the distinguishing perceptual features.

Experiment 1

Experiment 1 provided a first test of whether and how mentalizing, perceptual features, and heuristics are used to arrive at fair task distributions. In order to address the role of mentalizing, we manipulated whether the mappings between stimuli and responses were unique or ambiguous. In the unique condition, both stimulus features (form and colour) required the same response in a two-choice task. In the ambiguous condition, one stimulus feature required one response and the other stimulus feature required the other response. If mentalizing is used to try to arrive at a fair task distribution, ambiguous mappings should create additional coordination problems that have to be solved by reasoning about which stimulus feature a partner will react to. This ambiguity should only matter when tasks are distributed between two partners but not when tasks are distributed between two hands.

In order to investigate whether perceptual features of a stimulus sequence are used to arrive at fair task distributions, we manipulated the sequences such that the perceptual features distinguishing subtasks either alternated by one, alternated by two, or alternated by four. If perceptual features are used to achieve a fair task distribution, partners can simply make their task distribution according to how the perceptual features alternate. This would require little to no planning.

Alternatively, if heuristics are used to plan a task distribution, then sequences with perceptual features that alternate by one or only once in the middle of the sequence should be easier and faster to plan for. Sequences with features that alternate by one should support a turn-taking heuristic so that participants alternate in responding. Sequences with features that alternate only once in the middle of the sequence (e.g., after 4 items in a sequence of 8 items) would suggest that pairs divide the sequence into two equal parts, supporting a minimal coordination heuristic. Sequences with perceptual features that alternate by two would not clearly suggest using any of the two heuristics. If heuristics are used, then partners should disregard the perceptual features and switch independently of the colour and form, either taking turns each time or minimizing the number of turns. Alternatively, if perceptual features dominate task distribution, then partners should simply follow how the features alternate and switch turns in responding after each second subtask.

Regardless of the way in which pairs achieve successful task distribution, one would expect that it takes pairs longer to discover and agree on a successful way of distributing the task. Once this is established, pairs should persist in using the same way of task distribution throughout the experiment. Individuals may show more variability because they do not have to coordinate with a partner.

Method

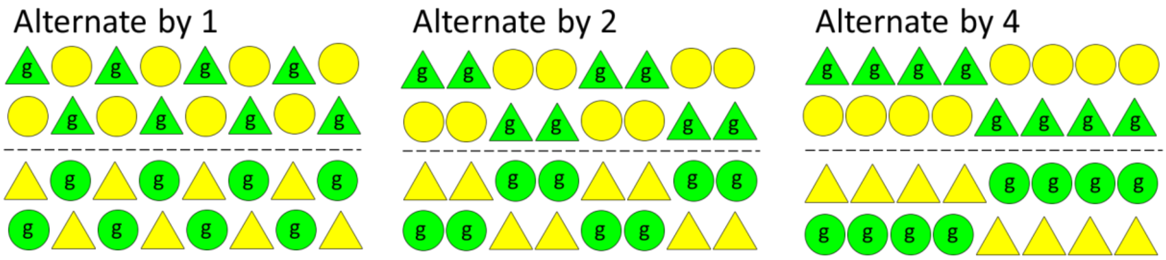
Participants. Sixty-seven participants (42 females, age range 19 – 44 years) were recruited through the university's SONA system and a student organization. Twenty-three participants were assigned to the individual condition and 44 participants were assigned to the joint condition, performing the task in 22 pairs. Participants were reimbursed with vouchers worth 1500 Hungarian forints or 1500 Hungarian forints in cash. All participants reported at least conversational skill in English and normal colour vision. The experimental protocol was approved by the United Ethical Review Committee for Research in Psychology, Hungary.

Material and Apparatus. In the individual condition, a 22-inch monitor was set on the table about 50cm away from where the participant was seated. On the table between the monitor and the participant was a controller box with four white circular buttons. Only the two outer buttons were used in the experiment. For the joint condition the setup was duplicated in a separate room (the two individuals in the joint condition could neither see each other nor talk to each other). The two monitors in the two rooms were connected to the same computer (Dell Precision, T5610). The experiment was programmed using E-prime 2.0 on the Windows 7.0 Professional operating system.

Figure 1 displays the twelve different stimulus sequences used in Experiment 1. All sequences consisted of eight items that required eight separate responses. Each item consisted of a combination from two forms (triangle, circle) and two colours (yellow, green). Each individual sequence used only two out of the four elements, yellow triangles and green circles, or yellow circles and green triangles. The items in these sequences either alternated by one (i.e., A-B-A-B-A-B-A-B), two (i.e., A-A-B-B-A-A-B-B), or four (i.e., A-A-A-A-B-B-B-B), so that items switched either 7 (Alternate by 1) times, 3 times (Alternate by 2), or once (Alternate by 4).

Figure 1

Stimulus Sequences Used in Experiment 1



Note. For purpose of contrast on monochrome displays, items labelled with ‘g’ are green in colour; items not labelled are yellow in colour. No labels were used in the actual experiment. Sequences in the three columns differ in how often the items in a sequence alternate. Sequences above the dotted lines implied ambiguous task mappings (different responses required for colour and form, e.g., ‘left for triangle and ‘right’ for green), sequences below the dotted lines implied no ambiguity (same response required for colour and form).

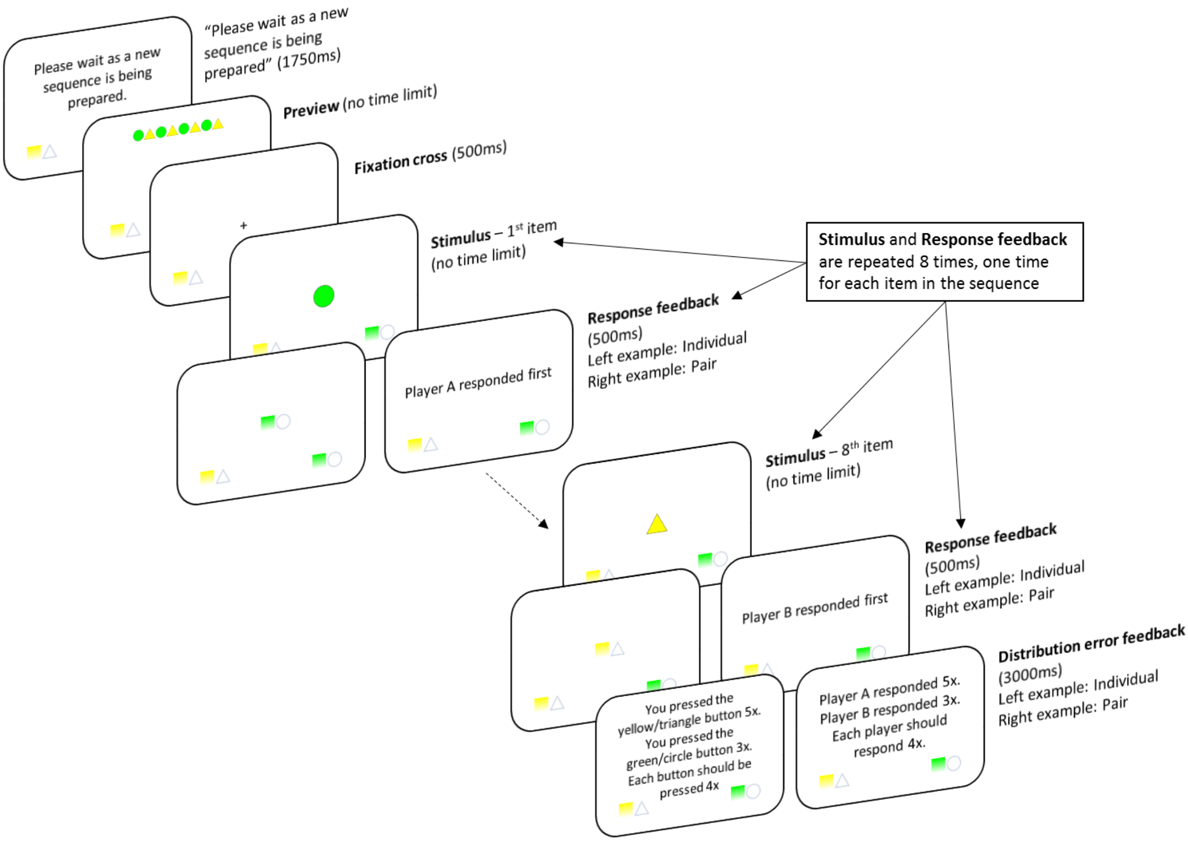
Procedure. After participants signed informed consent, they were introduced to the experimental setup. Participants in the joint condition were randomly assigned to the two experimental rooms. Participants were informed that their task was to respond to sequences of eight items and that a preview of the eight items would be first presented in each trial. The instructions encouraged them to plan in advance how to respond to the whole sequence of items so that both individuals in a pair respond equally often (in the joint condition) or so that each of the two buttons is pressed equally often (in the individual condition).

The task for each item in a sequence was to respond to yellow items OR triangles with the left key, and to green items OR circles with the right key. Importantly, this implies that participants could choose which stimulus dimension to respond to. For 6 out of the 12 stimulus sequences, this created a task ambiguity because the different stimulus dimensions of colour and form required different responses (see Figure 1). For instance, a yellow circle required pressing the left button when responding to colour and pressing the right button when responding to form. Note that this task ambiguity implied that pressing any of the two available buttons yielded a correct response. For the remaining six stimulus sequences, there was no task ambiguity because form and colour required the same response for each item. For instance, a yellow triangle required a left response, regardless of whether a participant responded to form or colour. Participants were instructed to respond to each item in the sequence as quickly as possible after the planning period.

The experiment started with a short familiarization phase where the procedure and the main elements of the task were introduced to the participants. In each trial of the experiment (see Figure 2), participants in the joint condition were first shown a preview of the eight-item sequence. There was no time limit to the preview.

Figure 2

Sequence of Events For Each Trial in Experiment 1



Note. The mappings of stimulus features to response keys were displayed on the bottom of the screen throughout the entire experiment.

Each participant pressed a button when ready to proceed. Only when both participants were ready to proceed did the trial continue. A fixation cross then appeared in the centre of the screen for 500ms. After the fixation cross, each stimulus item in the sequence appeared individually, in the centre of the screen, and remained there until a response was made. The first button press performed by either of the two participants was counted as the response. Depending on who in the pair pressed the button first, a "Player A responded first" or "Player B responded first" feedback was shown for 500ms. After all eight items in the sequence had been shown and eight responses had been collected, a feedback appeared for 3000ms if the task distribution between players was not equal (equal task distribution required that each player responded to four of the eight items in a sequence). This distribution error feedback listed the number of responses made by each player and reminded participants that "Each player should respond 4 times". Before the preview for the next trial began, participants received a message "Please wait as a new sequence is being prepared" for 1750ms.

The events in each trial were the same in the individual condition with the following exceptions. After each response an individual performed, the key mapping of the button they had pressed, as indicated through a square patch of colour (either yellow or green) and an outline of a form (either triangle or circle), was displayed in the centre of the screen for 500ms. If there was a task distribution error, the error feedback listed the number of responses made per button and reminded participants that "Each button should be pressed 4 times" (see Figure 2).

The 12 sequences were presented in random order in 12 blocks with four repetitions of the same sequence per block. Thus, there were 48 trials total. The main experiment took an average of 11.6 minutes for individuals and 17.1 minutes for pairs to complete.

Results

We analysed response errors, task distribution errors, preview time for sequences, average reaction time to items in a sequence, the number of switches made per sequence, the frequency of use for each strategy, and the effects of strategy discovery on performance. One pair and one individual were excluded from the analyses due to technical errors. One individual was excluded because total errors deviated more than three standard deviations from the mean in the individual condition.

Attempting to achieve a fair task distribution does not necessarily lead to a successful task distribution. Therefore, we included trials in which a fair task distribution was not achieved in the analyses of preview times, reaction times, number of switches made, and strategy use. For ambiguous sequences, response error was zero for all participants because either button press was correct under the form or colour response mapping. Within the Ambiguous Mapping condition, there was a slight preference for performing the colour task (58.7% in the individual condition and 55.5% in the joint condition).

Where not indicated otherwise, results were analysed with a 2 x 2 x 3 mixed ANOVA with the between-subject factor Condition (Individual, Joint) and the within-subject factors Task Type (Ambiguous Mapping, Unique Mapping) and Feature Alternation (1, 2, 4).

Response Errors. This measure could only be computed for the Unique Mapping condition, where response errors could be committed. Table 1 displays the error rates.

Table 1

Mean Percentage of Response Errors and Standard Deviations by Condition

Feature Alternation	Individual (*n* = 21)		Pair (*n* = 21)	
	M	*SD*	*M*	*SD*
1	2.4	4.4	8.3	8.6
2	1.7	3.6	6.8	8.9
4	4.4	6.3	4.9	7.4

Pairs committed more response errors (*M* = 6.7%, *SD* = 7.2%) than individuals (*M* = 2.8%, *SD* = 3.8%). A mixed 2-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factor Feature Alternation (1, 2, 4) resulted in a significant main effect of Condition, $F(1, 40) = 4.72$, $p = .036$, $\eta^2 = .11$. There was no significant main effect of Feature Alternation, $F(1.59, 63.78) = 0.58$, $p = .526$, $\eta_p^2 = .01$, but a significant interaction, $F(1.59, 63.78) = 4.37$, $p = .024$, $\eta_p^2 = .10$. Pairs committed more response errors than individuals in sequences where items alternated by 1 or 2.

Task Distribution Errors. Table 2 displays the percentage of task distribution errors across the different conditions. The mixed 3-way ANOVA revealed a significant main effect of Condition, $F(1, 40) = 18.02$, $p < .001$, $\eta^2 = .31$. Pairs committed substantially more task distribution errors (*M* = 32.3%, *SD* = 27.3%) than individuals (*M* = 6.8%, *SD* = 4.4%). There was no significant main effect of Feature Alternation, $F(2, 80) = 1.31$, $p = .276$, $\eta_p^2 = .03$, and Task Type, $F(1, 40) = 1.35$ $p = .251$, $\eta_p^2 = .03$, and there were no significant interactions.

Table 2

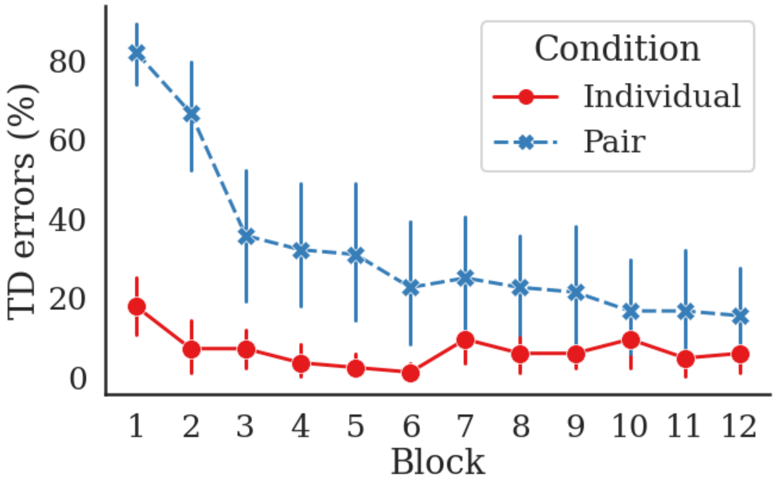
Mean Percentage of Task Distribution Errors and Standard Deviations by Condition

Feature Alternation	Individual (*n* = 21)		Pair (*n* = 21)	
	M	*SD*	*M*	*SD*
1	5.4	6.9	31.8	32.5
2	5.4	4.1	31.0	29.5
4	9.5	8.3	34.2	27.6

An additional Greenhouse-Geisser corrected mixed 2-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factor Block (1-12) revealed that the proportion of task distribution errors significantly decreased over time, $F(5.58, 223.37) = 19.48$, $p < .001$, $\eta_p^2 = .33$. The interaction between Block and Condition was significant, $F(5.58, 223.37) = 11.70$, $p < .001$, $\eta_p^2 = .23$. Task distribution errors decreased to a much larger extent in pairs than in individuals (see Figure 3).

Figure 3

Mean Proportion of Task Distribution Errors Across All 12 Blocks

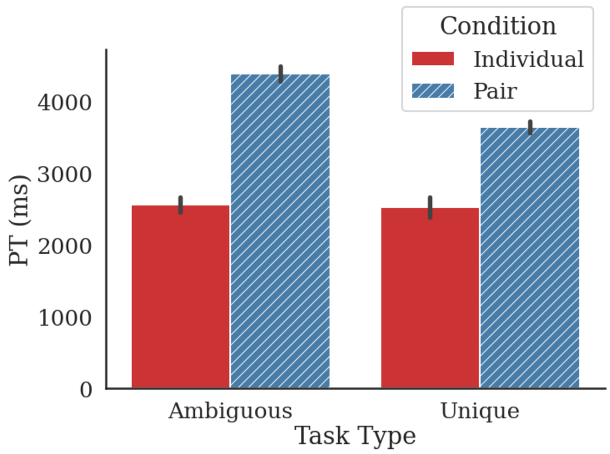


Note. Error bars are 95% confidence intervals.

Preview Time. Preview Time (PT) was computed as the time interval from the onset of the preview of the sequence until participants pressed a button to indicate that they were ready to respond to the sequence. The mixed 3-way ANOVA revealed a significant main effect of Condition, $F(1, 40) = 14.60$, $p < .001$, $\eta^2 = .27$. Pairs took longer preview times ($M = 4010$ms, $SD = 1010$ms) than individuals ($M = 2539$ms, $SD = 1447$ms).

Figure 4

Preview Time (ms) by Task Type

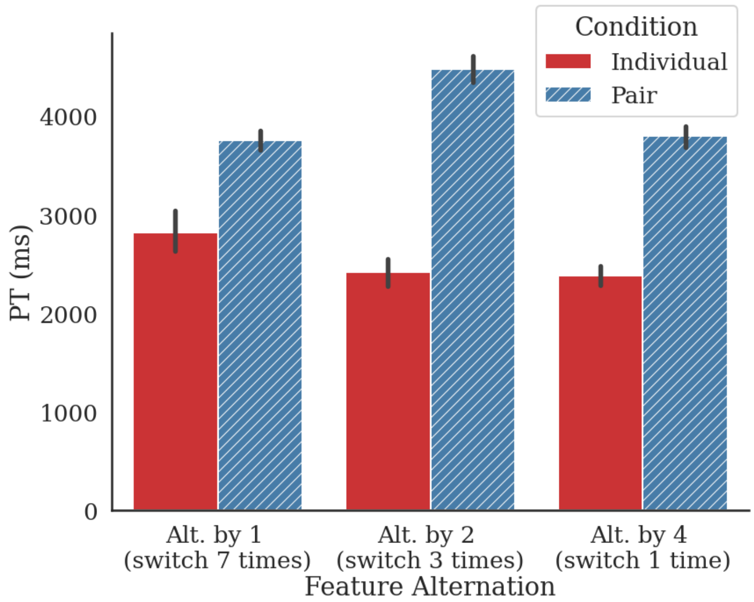


Note. Error bars are 95% confidence intervals.

There was also a significant main effect of Task Type, *F*(1, 40) = 8.91, *p* = .005, η_p^2 = .18. Preview times for Ambiguous Mapping sequences (*M* = 3469ms, *SD* = 1550ms) were longer than for Unique Mapping sequences (*M* = 3080ms, *SD* = 1469ms). A significant interaction between Task Type and Condition, *F*(1, 40) = 7.42, *p* = .010, η_p^2 = .16, showed that the difference between Ambiguous Mapping (*M* = 4383ms, *SD* = 1299ms) and Unique Mapping sequences (*M* = 3638ms, *SD* = 892ms) was large in groups and practically absent in individuals (*M* = 2556ms, *SD* = 1219ms vs. *M* = 2522ms, *SD* = 1725ms).

Figure 5

Preview Time (ms) by Feature Alternation



Note. Error bars are 95% confidence intervals.

There was no main effect of Feature Alternation on PT, *F*(1.71, 68.33) = 1.34, *p* = .268, η_p^2 = .03 (Huynh-Feldt corrected). There was, however, a significant interaction between Feature Alternation and Condition, *F*(1.71, 68.33) = 3.32, *p* = .049, η_p^2 = .08. Pairs were faster on sequences with features that alternated by 1 (*M* = 3755ms, *SD* = 1076ms) and 4 (*M* = 3795ms, *SD* = 1127ms) than for sequences with features that alternated by 2 (*M* = 4481ms, *SD* = 1480ms). For individuals, PT did not differ between the three levels of feature alternation of Alternate by 1 (*M* = 2819ms, *SD* = 2461ms), 2 (*M* = 2415ms, *SD* = 1177ms), and 4 (M = 2382ms, SD = 1164ms). The 3-way interaction of Feature Alternation, Task Type, and Condition was not significant, $F(1.78, 71.33) = 0.34$, $p = .686$, $\eta_p^2 = .01$.

Both pairs and individuals achieved a faster PT over time. Pairs started out at the first block and ended at the last block with a mean PT of 7309ms (SD = 2499ms) and 2784ms (SD = 1104ms), respectively. Individuals started out at the first block and ended at the last block with a mean PT of 5725ms (SD = 6863ms) and 1615ms (SD = 931ms), respectively. The Greenhouse-Geisser corrected mixed 2-way ANOVA showed a significant effect of Block on PT, $F(2.81, 112.46) = 17.40$, $p < .001$, $\eta_p^2 = .30$, but no interaction between Block and Condition, $F(2.81, 112.46) = 0.81$, $p = .486$, $\eta_p^2 = .02$.

Table 3

Mean Preview Time (ms) Across Factors

Feature Alternation	Individual (n = 21)		Pair (n = 21)	
	M	*SD*	*M*	*SD*
	Ambiguous Task Type			
1	2492	1575	3984	1656
2	2712	1826	4938	2058
4	2463	1399	4227	1676
Total	2556	1219	4383	1299
	Unique Task Type			
1	3146	3657	3526	966
2	2118	992	4023	1801
4	2301	1237	3364	968
Total	2522	1725	3638	892

Reaction Time. Reaction time (RT) was our measure for the average time participants took to respond to each item in a sequence. The mixed 3-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factors Task Type (Ambiguous Mapping, Unique Mapping) and Feature Alternation (1, 2, 4) revealed no main effects and no significant interactions. In the Greenhouse-Geisser corrected mixed 2-way ANOVA, there was however, a significant Block effect on RT, $F(4.31, 172.6) = 19.92$, p

< .001, η_p^2 = .33, and also a significant interaction effect of Block and Condition, *F*(4.314, 172.6) = 4.40, *p* = .002, η_p^2 = .10. Individuals showed a greater decrease in RT than pairs across consecutive blocks. Pairs started out at the first block and ended at the last block with a mean RT of 428ms (*SD* = 196ms) and 248ms (*SD* = 196ms) respectively. Individuals started out at the first block and ended at the last block with a mean RT of 640ms (*SD* = 289ms) and 238ms (*SD* = 94ms) respectively.

Table 4

Mean Reaction Time (ms) Across Factors

Feature Alternation	Individual (*n* = 21)		Pair (*n* = 21)	
	M	*SD*	*M*	*SD*
	Ambiguous Task Type			
1	330	146	289	107
2	321	181	298	127
4	315	121	286	143
Total	322	125	291	96
	Unique Task Type			
1	322	148	288	125
2	308	126	294	129
4	286	88	281	144
Total	305	86	287	111

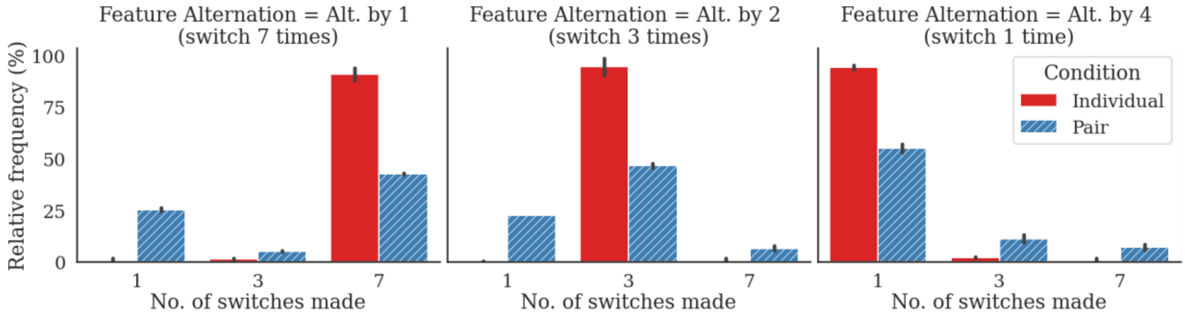
Switches per Sequence. The number of switches between players or hands provides a direct measure of how participants distributed the task sequences. The mixed 3-way ANOVA (Greenhouse-Geisser corrected) revealed no main effects of Condition and Task Type. Feature Alternation, however, had a significant effect on the number of switches, *F*(1.21, 48.38) = 200.25, *p* < .001, η_p^2 = .83. There was also a significant interaction effect of Feature Alternation and Condition, *F*(1.21, 48.38) = 41.00, *p* < .001, η_p^2 = .51. Switches in the individual condition closely followed the switches in perceptual features of the sequence regardless of Task Type. When features alternated by one and thus supported seven switches, individuals switched an average of 6.71 (*SD* = 0.56) times and 6.82 (*SD* = 0.37) times with the Ambiguous Mapping and Unique Mapping tasks respectively. When features alternated by two and supported three switches, individuals switched an average of 3.05 (*SD* = 0.44) times and 3.02 (*SD* = 0.09) times with the Ambiguous Mapping and Unique Mapping tasks respectively. When features alternated by four and supported one switch, individuals switched an average of 1.19 (*SD* = 0.74) times and 1.05 (*SD* = 0.12) times with the Ambiguous Mapping and Unique Mapping tasks respectively.

There was some indication in pairs that a high number of switches in perceptual features led to a higher number of switches, but the differences between levels of alternation were much less pronounced in pairs. When features alternated by one and supported seven switches, pairs switched an average of 4.30 (*SD* = 2.40) times and 4.15 (*SD* = 2.46) times with the Ambiguous Mapping and Unique Mapping tasks respectively. When features alternated by two and supported three switches, pairs switched an average of 2.70 (*SD* = 1.15) times and 2.82 (*SD* = 1.37) times with the Ambiguous Mapping and Unique Mapping tasks respectively. When features alternated by four and supported one switch, pairs switched an average of 2.10 (*SD* = 1.40) times and 2.14 (*SD* = 1.26) times with the Ambiguous Mapping and Unique Mapping tasks respectively.

Figure 6 plots the relative frequency of the number of switches. Across all levels of feature alternation, pairs switched one time (i.e., minimizing turns) or 7 times (i.e., turn taking) more frequently than individuals. Individuals switched according to how features in the sequence alternated for 90.2% (*SD* = 8.9%) of the total sequences while pairs switched in the same manner for only 43.1% (*SD* = 30.1%). This difference between conditions was significant, $t(23.5) = 6.88$, $p < .001$, $d = 2.12$ (corrected for unequal variances).

Figure 6

Relative Frequency of the Number of Switches Made Across the Different Feature Alternation Levels



Note. Error bars are 95% confidence intervals.

Strategy Use. When and where participants switched between hands or partners in a task sequence is indicative of which strategy they use. Using perceptual features as a strategy would imply switching when perceptual features of the sequences switched while using turn-taking would imply switching after every item. Minimal coordination would be switching once exactly after four items in the sequence. For sequences with features that alternate by one, use of turn-taking and use of perceptual features cannot be distinguished. Therefore, these sequences were omitted from the analyses for turn-taking and use of perceptual features. For sequences with features that alternate by four, use of minimal coordination and use of perceptual features cannot be distinguished. Therefore, these sequences were omitted from the analyses for minimal coordination and use of perceptual features. Thus, only sequences that alternate by two were used for analysis of the perceptual features strategy.

To examine the use of perceptual features as a strategy, a mixed 2-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factor Task Type (Ambiguous Mapping, Unique Mapping) was run with only sequences where features alternated by two. There was a significant main effect of Condition, $F(1, 40) = 30.90$, $p < .001$, $\eta^2 = .44$, and of Task Type, $F(1, 40) = 5.99$, $p = .019$, $\eta_p^2 = .13$. Individuals switched according to how the features alternated 91.4% (SD = 10.2%) of the time while pairs switched in the same manner 39.0% (*SD* = 42.0%) of the time. Overall, perceptual features were used 34.5% (*SD* = 20.7%) of the time when Task Type was unique, and 30.7% (*SD* = 20.7%) of the time when Task Type was ambiguous. The interaction between Condition and Task Type was not significant, $F(1, 40) = 0.14$, $p = .709$.

To examine the use of turn-taking as a strategy, a mixed 3-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factors Task Type (Ambiguous Mapping, Unique Mapping) and Feature Alternation (2, 4) was run. There were no effects of Condition, $F(1, 40) = 2.60$, $p = .115$, $\eta^2 = .06$, Task Type, $F(1, 40) = 0.59$, $p = .448$, $\eta_p^2 = .01$, nor of Feature Alternation, $F(1, 40) = 0.04$, $p = .843$, $\eta_p^2 < .01$. Individuals used turn-taking 0.9% (*SD* = 4.1%) of the time while pairs employed turn-taking 6.8% (*SD* = 16.4%) of the time.

To examine the use of minimal coordination as a strategy, a mixed 3-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factors Task Type (Ambiguous Mapping, Unique Mapping) and Feature Alternation (1, 2) was run. There was only the significant main effect of Condition, $F(1, 40) = 6.05$, $p = .018$, $\eta^2 = .13$. Individuals used minimal coordination 0.4% (*SD* = 2.0%) of the time while pairs used minimal coordination 18.3% (*SD* = 33.2%) of the time. Feature Alternation had no effect, $F(1, 40) = 0.82$, $p = .371$, $\eta_p^2 = .02$, and neither did Task Type, $F(1, 40) = 0.05$, $p = .822$, $\eta_p^2 < .01$.

Strategy Discovery and its Effects on Performance. In the first step we analysed whether discovering a successful strategy led to a sudden reduction in task distribution errors. We determined the number of blocks that it took from the start to discover a strategy, under the assumptions that 1) up to 100% task distributions errors were made before discovering a successful strategy and 2) no errors were made after discovering a successful strategy. We call this measure ‘time to strategy discovery’. Then we computed the actual percentage of task distribution errors pairs and individuals committed in the time to strategy discovery. The closer this value is to 100%, the more sudden the task distribution errors decrease upon the discovery of a strategy. For pairs, the time to discovery was an average of 4.4 blocks (*SD* = 3.2 blocks) and for individuals, the time to discovery was estimated to be 1.3 blocks (*SD* = 0.6 blocks). This discovery time difference was significant, $t(21.2) = -4.39$, $p < .001$, $d = -1.35$. Pairs committed 80.4% (*SD* = 14.9%) of their task distribution errors in this time to discovery whereas individuals only committed 37.9% (*SD* = 36.4%) of the errors in this time to discovery. This difference was significant, $t(26.5) = -4.96$, $p < .001$, $d = -1.53$.

In the second step, we checked whether not using one of the successful strategies increased task distribution errors and whether using a successful strategy decreased preview times, as one should expect. To do so, we categorized trials into ‘strategy’ or ‘no strategy’ trials, based on switches between partners (joint condition) or hands (individual condition). If the pattern of switches corresponded to turn taking, minimal coordination, and/or following perceptual features, a trial was classified as a ‘strategy’ trial; all other trials were classified as ‘no strategy’ trials. The frequency of ‘no strategy’ trials was 8.9% (*SD* = 6.0%) in individuals and 40.2% (*SD* = 31.2%) in pairs. This difference was significant, $t(21.5) = -4.51$, $p < .001$, $d = -1.39$. A higher percentage of ‘no strategy’ trials was associated with a larger number of task distribution errors in individuals, $r(19) = .88$, $p < .001$, and pairs, $r(19) = .97$, $p < .001$. By definition, there were no task distribution errors in trials where successful strategies were used.

In addition, pairs had significantly longer preview times in ‘no strategy’ trials (*M* = 5455ms, *SD* = 2132ms) than in ‘strategy’ trials (*M* = 3721ms, *SD* = 1176ms), $t(20) = 3.91$, $p < .001$, $d = 0.85$. Individuals also took a longer preview time in ‘no strategy’ trials (*M* = 2966ms, *SD* = 2325ms) than in strategy trials (*M* = 2454ms, *SD* = 1414ms), but this difference was not significant, $t(20) = 1.32$, $p = .203$, $d = 0.29$. Pairs with a smaller percentage of ‘no strategy’ trials had longer PTs, $r(19) = -.59$, $p = .005$. There was no such correlation for individuals, $r(19) = .025$, $p = .285$. There were also no significant correlations between ‘strategy’ trials and PT for individuals, $r(19) = .09$, $p = .707$, and pairs, $r(19) = -.11$, $p = .651$.

Discussion

Experiment 1 addressed the role of mentalizing, perceptual features, and heuristics in achieving fair task distributions. The results provide evidence that when pairs distribute tasks in a joint action, they mentalize and rely on heuristics such as turn-taking and minimal coordination. When individuals distribute the same tasks between their two hands, they mainly follow perceptual features of the stimuli in a task sequence.

Regarding mentalizing, we predicted that pairs should mentalize more than individuals because they needed to think about the actions of their partner in relation to the joint task distribution. This prediction was supported by the result that pairs took significantly longer to plan task distributions than individuals. This indicates that partners thought about each other’s contributions to performing a sequence of tasks. A second indication that mentalizing was taking place while previewing sequences was that it took pairs longer to plan when the task mappings were ambiguous than when they were unique. The ambiguity in the mapping was likely perceived as creating additional coordination problems that pairs tried to resolve by thinking about each other’s task mapping. It is worth noting that there was no need to do this in the present task. It would have been perfectly possible for partners to ignore each other because under the ambiguous mapping, both response alternatives were correct for each task item (one response alternative for colour and one for form). In this sense, the ambiguous mapping condition required less thinking about one another than the unique mapping condition, yet pairs took longer to preview sequences with ambiguous task mappings.

Pairs did not seem to engage in additional monitoring of each other's task during the performance, which could be conceived of as another component of mentalizing. This is suggested by the result that reaction times were not slower in the joint condition. Results of RT across blocks indicate, instead, that participants were possibly speeding up in early trials to facilitate joint task distribution, the same way people do when trying to achieve temporal coordination (Vesper, Schmitz, Safra, Sebanz, & Knoblich, 2016; Vesper, Soutschek, & Schubo, 2009).

The results provide clear support for the hypothesis that pairs applied heuristics specifically dedicated to task distribution in social contexts. Pairs often distributed the items in a sequence in a way that either corresponded to minimal coordination (one switch between partners for the eight items in a sequence) or turn-taking (7 switches between partners for the eight items in a sequence) heuristics. Individuals did not show the same preference for these heuristics, particularly for minimal coordination.

The results also supported our prediction that if heuristics are used to plan a task distribution, sequences with perceptual features that support the use of heuristics should reduce the need for mentalizing for partners in a pair. Planning time was quicker for sequences where perceptual features (colour or form) alternated by one or four, supporting the use of turn-taking and minimal coordination heuristics, respectively. Importantly, this pattern of planning time difference between the different feature alternation types did not appear with individuals, demonstrating that heuristics use was specific to the social context instead of being of a more general nature.

Individuals, instead, relied solely on the perceptual features of a task to plan their task distribution. This is evident in the number of switches made for the different Feature Alternation types. The number of switches individuals made when distributing the items in a sequence between their two hands almost perfectly corresponded to how often perceptual features of the items switched in a sequence. There was no indication of a preference for turn-taking or minimal coordination.

The finding that pairs had longer preview times and committed more errors than individuals implies that it was harder for them to come up with a way to achieve a fair task distribution. This was confirmed in the analyses of strategy discovery. Whereas individuals were successful from the first block of trials, it took pairs four blocks of trials on average to discover a successful strategy. Once pairs had discovered a successful strategy, their task distribution errors immediately dropped and their preview times decreased, presumably because a further search for a successful task distribution strategy was not necessary anymore.

Despite pairs' higher proneness to commit task distribution errors, the result that pairs used dedicated social heuristics raises the possibility that there could be situations where groups can distribute tasks more effectively than individuals. This should occur when there is a low need for mentalizing, when perceptual features do not suggest a unique task distribution, and when there are unique mappings between perceptual features and button responses. This prediction was tested in the next experiment.

Experiment 2

In Experiment 2 we asked if social heuristics that support planning a task distribution can make pairs more effective than individuals in task distributions. This could be the case if there are unique task mappings and use of social heuristics potentially implies performance benefits. In this experiment, individuals and pairs worked only on sequences where perceptual features could potentially support heuristics use. Perceptual features either alternated from item to item or only once, in the middle of the sequence, supporting the turn-taking and minimal coordination heuristics respectively. We used two types of sequences. In sequences with unique alternation, the two perceptual features of an item (form, colour) alternated concurrently, supporting the use of the same heuristic. In sequences with ambiguous alternation, one perceptual feature alternated from item to item, whereas the other perceptual feature alternated only once, in the middle of the sequence (see Figure 7).

If perceptual features guide fair task distribution, then sequences with unique alternation should be easier and faster to distribute than sequences with ambiguous alternation. When form and colour of items in a sequence alternate together, a unique task distribution can be achieved with little or no planning by simply following the alternation of the two perceptual features from item to item. If perceptual features in a sequence have different rates of alternation, there will be a need to select which perceptual feature to follow. This need implies additional planning and would be expected to produce longer preview times for sequences with ambiguous alternation.

However, if perceptual features inform social heuristics that support joint task distribution, sequences with ambiguous alternation of perceptual features should not pose any additional difficulty. This is because the chosen social heuristics, turn taking or minimal coordination, would determine which perceptual feature should guide task distribution. No additional difficulty is thus expected for sequences with ambiguous alternation.

Regardless of whether pairs use social heuristics or perceptual features for task distribution, the clear task mappings in Experiment 2 should make it easier for pairs to discover a working strategy. In fact, they may be able to establish a certain way of distributing the task right from the start, just as individuals did in Experiment 1.

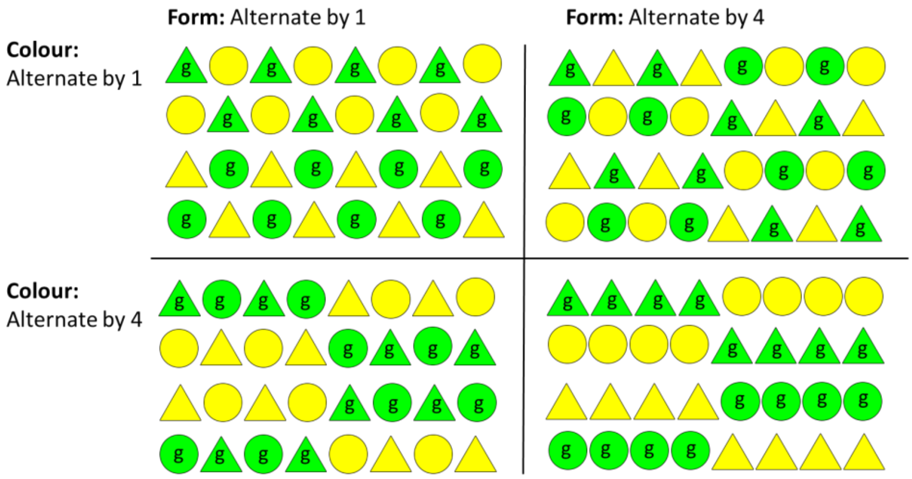
Method

Participants. Sixty-five participants (42 females, age range 18 – 32 years) were recruited through the university's SONA system and a student organization. Twenty-one participants were assigned to the individual condition and 44 participants were assigned to the joint condition, performing the task in 22 pairs. Participants were reimbursed with vouchers worth 1500 Hungarian forints or 1500 Hungarian forints in cash. All participants reported at least conversational skill in English and normal colour vision. The experimental protocol was approved by the United Ethical Review Committee for Research in Psychology, Hungary.

Material and Apparatus. Material and apparatus were the same as in the first experiment except for the sequences used. Figure 7 displays the 16 different stimulus sequences used in Experiment 2. In half of the sequences, form and colour alternated together, either from item to item (alternate by 1), or once in a sequence (alternate by 4). In half of the sequences, colour and form alternated at different rates.

Figure 7

Stimulus Sequences Used in Experiment 2

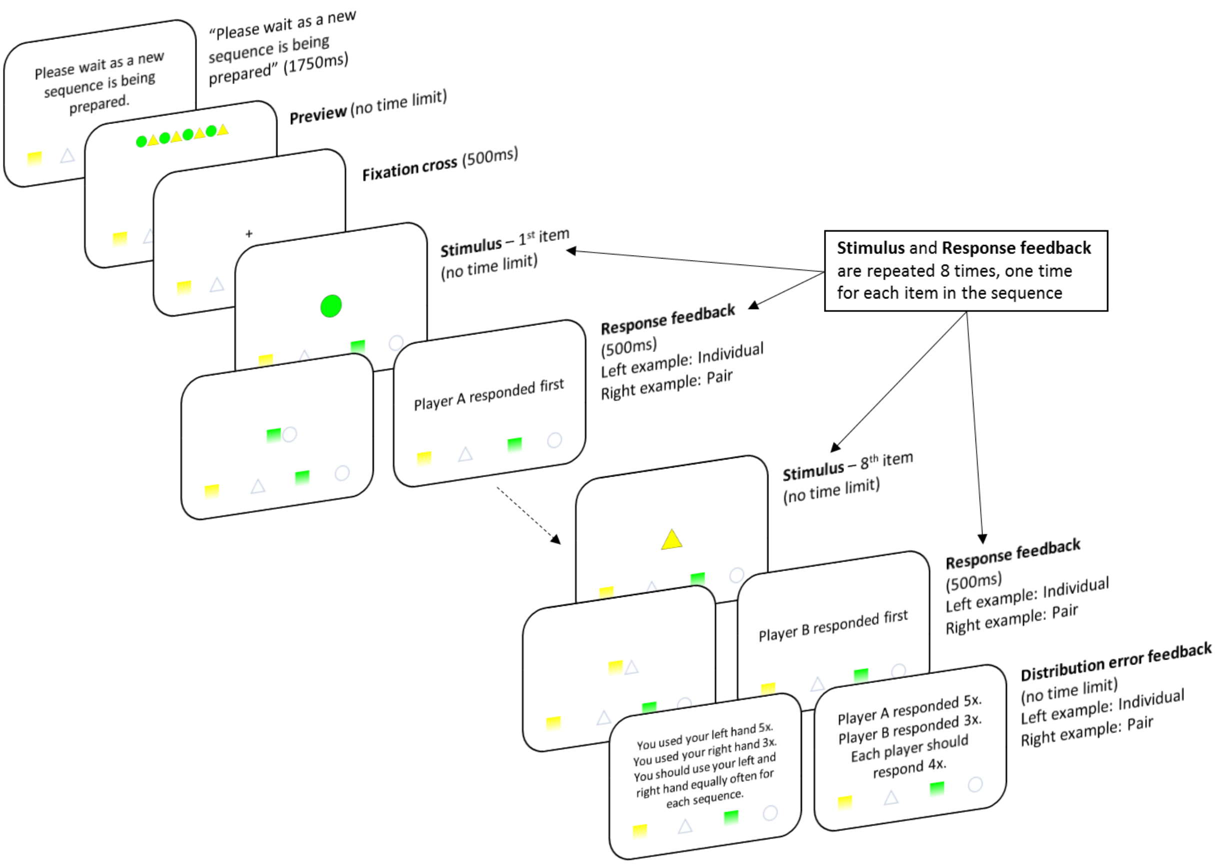


Note. For purpose of contrast on monochrome displays, items labelled with 'g' are green in colour; items not labelled are yellow in colour. No labels were used in the actual experiment.

Procedure. The procedure was the same as in Experiment 1 with the following exceptions: the task for each item in a sequence was to respond to either its colour or its form using four buttons. The two buttons on the left (yellow and triangle) were operated with the left hand and the two buttons on the right (green and circle) were operated with the right hand. Mapping of colours and forms to buttons were displayed on the screen throughout the whole experiment (see Figure 8). Participants could choose which perceptual feature to respond to. For each item in the sequence, two responses (one form response and one colour response) were correct.

Figure 8

Sequence of Events For Each Trial in Experiment 2



There was also a small change in the distribution error feedback in both conditions (Figure 8). The distribution error feedback remained on screen until participants responded by pressing any button (in the pair condition, both participants needed to respond).

The 16 sequences were presented in random order in 16 blocks with four repetitions of the same sequence per block. Thus, there were 64 trials total. The main experiment took an average of 19.1 minutes for individuals and 23.0 minutes for pairs to complete.

Results

We analysed the same variables as in Experiment 1. Where not indicated otherwise, results were analysed with a 2 x 2 x 2 mixed ANOVA with the between-subject factor Condition (Individual, Joint) and the within-subject factors Sequence Type (Ambiguous, Unique) and Colour Alternation (1, 4). The latter factor was included to measure the effect of the number of alternations in a sequence. (Using Form Alternation as a factor would lead to the same pattern of results.)

Three pairs and two individuals were excluded from the analyses because their responses errors deviated more than three standard deviations from the mean in their respective conditions. Data from one pair was not saved due to technical error. From the correct responses across all sequences, individuals showed a slight preference for performing the form task (56.4%). Pairs showed no such preference, performing the form task in 50.3% of the trials.

Response Errors. The error rate was low and did not differ significantly between individuals (M = 2.0%, SD = 1.9%) and pairs (M = 1.8%, SD = 1.2%), $F(1, 35) = 0.14$, $p = .711$, $\eta^2 < .01$.

Table 5

Mean Percentage of Response Errors and Standard Deviations by Factors

Colour Alternation	Individual (*n* = 19)		Pair (*n* = 18)	
	M	*SD*	*M*	*SD*
	Ambiguous Sequence Type			
1	2.2	2.9	2.0	3.1
4	2.3	2.1	2.0	2.2
Total	2.2	2.0	2.0	1.8
	Unique Sequence Type			
1	2.3	4.1	1.6	2.0
4	1.1	1.0	1.4	1.5
Total	1.7	2.3	1.5	1.4

Task Distribution Errors. The task distribution error rate was low and did not differ significantly between individuals (*M* = 7.0%, *SD* = 5.5%) and pairs (*M* = 4.4%, *SD* = 3.8%), $F(1, 35) = 2.71$, $p = .109$, $\eta_p^2 = .07$.

Table 6

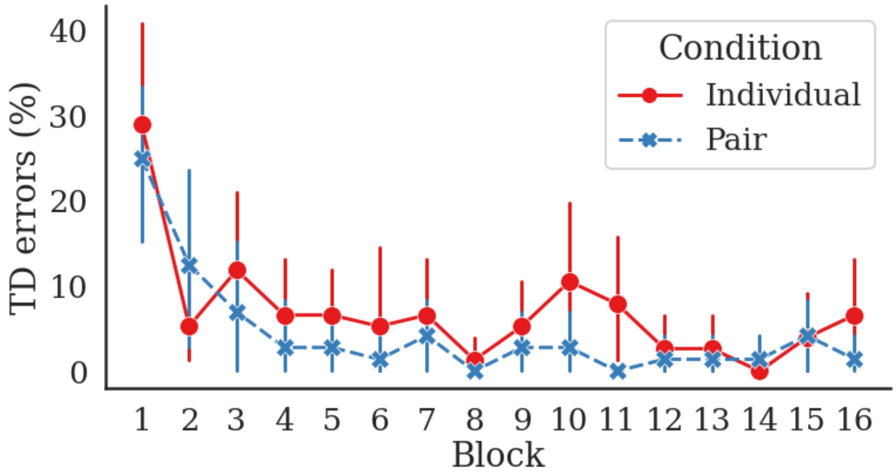
Mean Percentage of Task Distribution Errors and Standard Deviations by Factors

Colour Alternation	Individual (*n* = 19)		Pair (*n* = 18)	
	M	*SD*	*M*	*SD*
	Ambiguous Sequence Type			
1	8.9	9.8	2.8	4.4
4	6.9	6.9	4.2	5.7
Total	7.9	7.5	3.5	3.7
	Unique Sequence Type			
1	4.6	5.0	2.4	3.8
4	7.6	8.5	8.3	11.9
Total	6.1	5.9	5.4	6.8

A Greenhouse-Geisser corrected mixed 2-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factor Block (1-16) revealed that the proportion of task distribution errors significantly decreased over time, $F(6.86, 240.15) = 9.14$, $p < .001$, $\eta_p^2 = .21$. The interaction was not significant, $F(6.86, 240.15) = 0.79$, $p = .593$, $\eta_p^2 = .02$.

Figure 9

Mean Proportion of Task Distribution Errors Across All 16 Blocks



Note. Error bars are 95% confidence intervals.

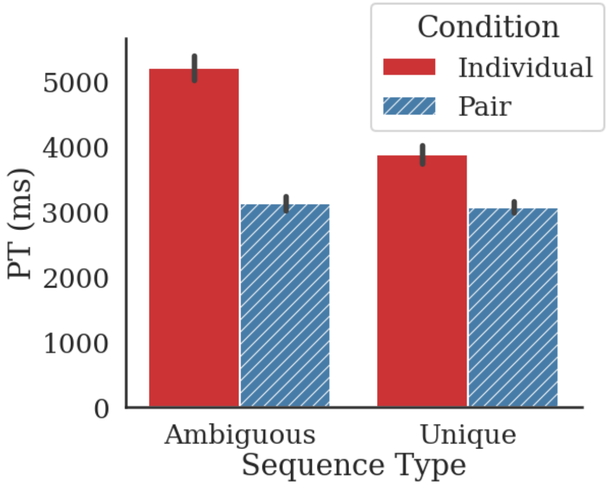
Preview Time. There was a significant main effect of Condition, $F(1, 35) = 4.80$, $p = .035$, $\eta^2 = .12$. Pairs had significantly shorter preview times (*M* = 3105ms, *SD* = 3230ms) than individuals (*M* = 4556ms, *SD* = 5950ms). There was also a main effect of Sequence Type, $F(1, 35) = 11.27$, $p = .002$, $\eta_p^2 = .24$, qualified by a significant interaction between Sequence Type and Condition, $F(1, 35) = 9.55$, $p = .004$, $\eta_p^2 = .21$. Individuals took longer for Ambiguous sequences (*M* = 5220ms, *SD* = 3040ms) than for Unique sequences (*M* = 3891ms, *SD* = 2366ms). Pairs had a smaller PT difference between Ambiguous sequences (*M* = 3133ms, *SD* = 1270ms) and Unique sequences (*M* = 3078ms, *SD* = 980ms). Colour Alternation had no significant effect, $F(1, 35) = 0.42$, $p = .519$, $\eta_p^2 = .01$. There were no further significant interactions.

Planning time decreased for pairs and individuals over time. Pairs started out at the first block and ended at the last block with a mean PT of 6708ms (*SD* = 2719ms) and 1997ms (*SD* = 1081ms) respectively. Individuals started out at the first block and ended at the last block with a mean PT of 9424ms (*SD* = 5899ms) and 3424ms (*SD* = 2592ms) respectively. A Greenhouse-Geisser corrected mixed ANOVA showed a significant main effect of Block,

$F(6.74, 235.89) = 14.3$, $p < .001$, $\eta_p^2 = .29$, but no interaction between Block and Condition, $F(6.74, 253.89) = 0.75$, $p = .622$, $\eta_p^2 = .02$.

Figure 10

Preview Time (ms) by Sequence Type

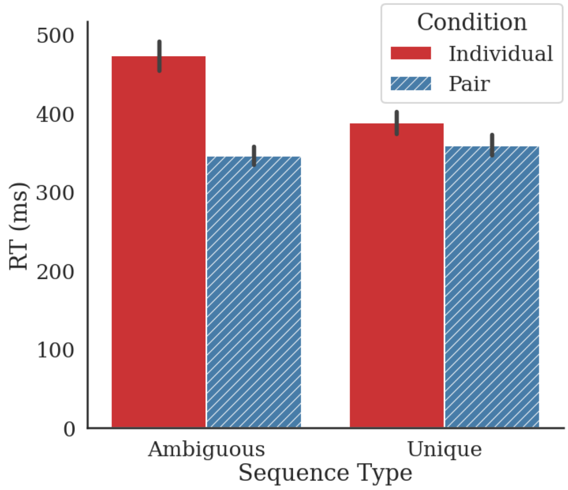


Note. Error bars are 95% confidence intervals.

Reaction Time. There were no main effects but a significant interaction of Condition and Sequence Type, $F(1, 35) = 4.99$, $p = .032$, $\eta_p^2 = .13$, and of Condition and Colour Alternation, $F(1, 35) = 5.22$, $p = .029$, $\eta_p^2 = .13$. Individual RTs were longer for Ambiguous sequences (*M* = 474ms, *SD* = 357ms) than for Unique sequences (*M* = 388ms, *SD* = 256ms). By comparison, pairs were not much different in RT for Ambiguous sequences (*M* = 346ms, *SD* = 152ms) and Unique sequences (*M* = 359ms, *SD* = 151ms). Individuals were also slower for sequences with Colour Alternation: 1 (*M* = 450ms, *SD* = 344ms) than for sequences with Colour Alternation: 4 (*M* = 412ms, *SD* = 262ms). Reaction time differences between Colour Alternation types were in the different direction for pairs. Pairs were slower for sequences with Colour Alternation: 4 (*M* = 371ms, *SD* = 154ms) than for sequences with Colour Alternation: 1 (*M* = 371ms, *SD* = 154ms). There were no further significant interactions.

Figure 11

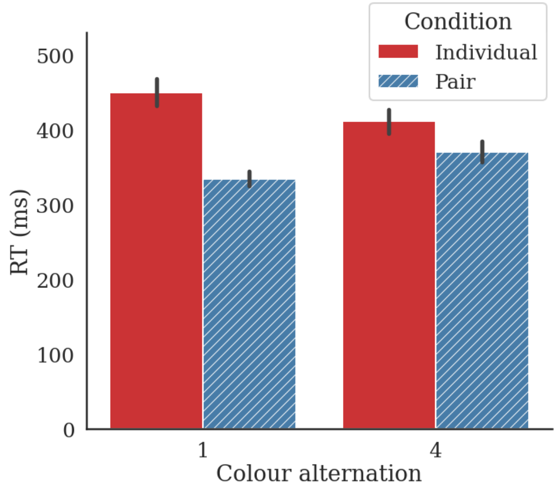
Reaction Time (ms) by Sequence Type



Note. Error bars are 95% confidence intervals.

Figure 12

Reaction Time (ms) by Colour Alternation



Note. Error bars are 95% confidence intervals.

A Greenhouse-Geisser corrected mixed ANOVA revealed a significant Block effect on RT, $F(4.21, 147.46) = 18.4$, $p < .001$, $\eta_p^2 = .35$, but there was no significant interaction with Condition. Pairs started out at the first block and ended at the last block with a mean RT of 706ms (*SD* = 302ms) and 290ms (*SD* = 178ms) respectively. Individuals started out at the first block and ended at the last block with a mean RT of 838ms (*SD* = 632ms) and 328ms (*SD* = 268ms) respectively.

Switches per Sequence. Figure 13 and Figure 14 show the relative frequency for the number of switches for individuals and pairs. While Colour Alternation and the Sequence Type made a large difference for the number of switches in individuals, these factors did not affect the number of switches in pairs. When colours alternated by one and supported seven switches, individuals switched an average of 3.71 (*SD* = 1.48) times and 6.54 (*SD* = .53) times with the Ambiguous and Unique sequences respectively. When colours alternated by four and supported one switch, individuals switched an average of 4.23 (*SD* = 1.39) times and 1.70 (*SD* = 0.88) times with the Ambiguous and Unique sequences respectively. In contrast, when colours alternated by one and supported seven switches, pairs switched an average of 3.99 (*SD* = 2.79) times and 4.31 (*SD* = 2.89) times with the Ambiguous and Unique sequences respectively. When colours alternated by four and supported one switch, individuals switched an average of 3.51 (*SD* = 2.81) times and 3.77 (*SD* = 2.76) times with the Ambiguous and Unique sequences respectively.

The ANOVA revealed a significant main effect of Colour Alternation, $F(1, 35) = 54.55$, $p < .001$, $\eta_p^2 = .61$, and significant interactions between Colour Alternation and Condition, $F(1, 35) = 21.04$, $p < .001$, $\eta_p^2 = .38$, and between Colour Alternation and Sequence Type, $F(1, 35) = 109.12$, $p < .001$, $\eta_p^2 = .76$. The three-way interaction of Sequence Type, Colour Alternation, and Condition was also significant, $F(1, 35) = 104.41$, $p < .001$, $\eta_p^2 = .75$.

Figure 13

Frequency of 1 and 7 Switches Made by Individuals Across Factors

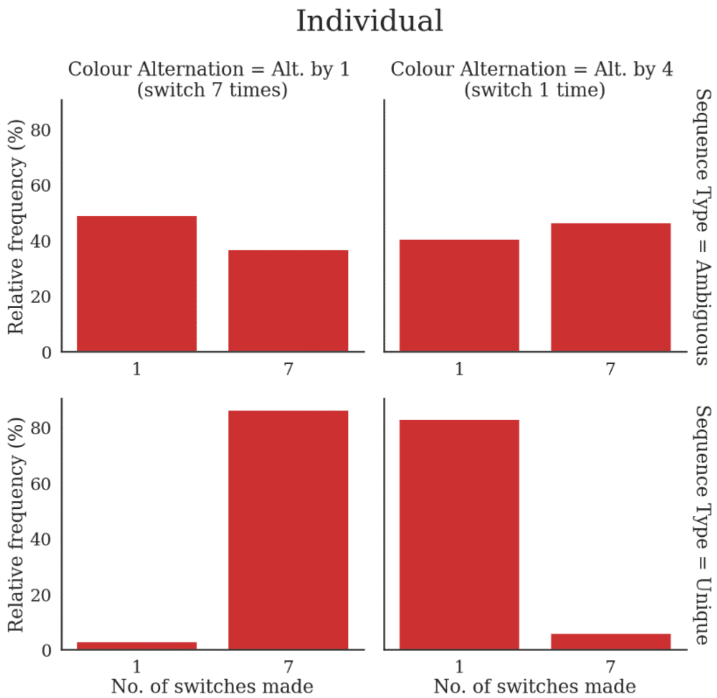
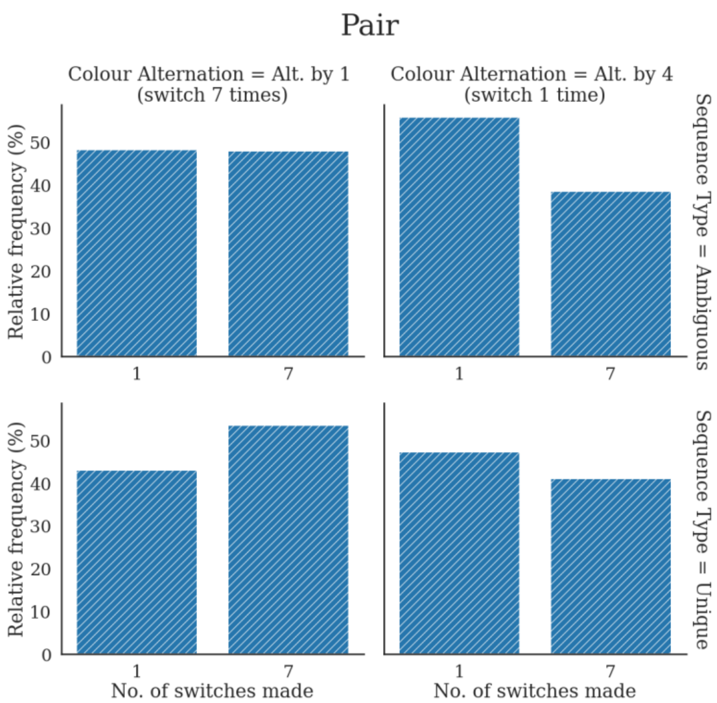


Figure 14

Frequency of 1 and 7 Switches Made by Pairs Across Factors



To examine further how individuals and pairs switched while working on a sequence, we computed the percentage of sequences where individuals' and pairs' switches either strictly followed form or strictly followed colour. A *t*-test revealed that individuals (M = 60.2%, SD = 25.3%) significantly more often followed form or colour than pairs (M = 40.3%, SD = 29.6%), $t(35) = 2.20$, $p = .034$, $d = 0.73$.

Strategy Discovery and its Effects on Performance. For individuals, the time to strategy discovery was estimated at 1.4 blocks (SD = .8 blocks), and 30.8% (SD = 26.4%) of the errors were made in this time. For pairs, the time to strategy discovery was 1.1 blocks (SD = 0.7 blocks), and 67.2% (SD = 32.2%) of the errors were made in this time. Only the difference in error rates between individuals and pairs was significant, $t(35) = -3.77$, $p < .001$, $d = -1.24$. There was no significant difference between individuals and pairs for time to discovery, $t(35) = 1.70$, $p = .099$, $d = 0.56$.

As in the previous experiment, we checked whether not using a successful strategy increased task distribution errors and whether using a successful strategy decreased preview times. The frequency of 'no strategy' trials was 14.2% (SD = 10.9%) for individuals and 7.0% (SD = 5.1%) for pairs. This difference was significant, $t(26.0) = 2.60$, $p = .015$, $d = 0.85$ (corrected for unequal variances). A higher percentage of 'no strategy' trials was associated with a larger number of TD errors in individuals, $r(17) = .70$, $p < .001$, and pairs, $r(16) = .82$, $p < .001$. Individuals also had significantly longer preview times in 'no strategy' trials (M = 6564ms, SD = 4743ms) than in 'strategy' trials (M = 4254ms, SD = 2237ms), $t(18) = 3.04$, $p = .007$, $d = 0.70$. Two pairs were able to use a strategy for all trials in the experiment and so they had no preview time data under 'no strategy' trials. Overall, pairs also had significantly longer preview times in 'no strategy' trials (M = 5925ms, SD = 3362ms) than in 'strategy' trials (M = 2888ms, SD = 852ms), $t(15) = 3.82$, $p = .002$, $d = 0.96$. There were no significant correlations between the percentage of ‘strategy’/‘no strategy’ trials and PT in individuals and pairs.

Discussion

The results of Experiment 2 bore out our prediction that, in certain situations, pairs can be more effective in distributing tasks than individuals. We predicted that the use of dedicated social heuristics by pairs should make planning easier and faster than for individuals not using heuristics, especially when perceptual features of a task sequence do not provide a clear indication of how to distribute a task.

Support for this prediction comes from our results of preview time, task distribution errors, and of our analyses of task distributions. Overall, pairs had significantly shorter planning time than individuals. This effect was more pronounced when the perceptual features in a task sequence alternated in an ambiguous way (i.e., when colour alternated from item to item, and form only once in the middle of a sequence of eight items). Furthermore, pairs’ planning times were not affected by whether the two perceptual features in a sequence, colour and form, supported the same task distribution or not. In contrast, individuals took longer to plan when the perceptual features in a task sequence did not follow the same alternation rate.

Further support for the interpretation that individuals relied on perceptual features while pairs used social task distribution heuristics comes from the number of switches observed in the unique sequences. Individuals clearly followed the alternations of perceptual features, whereas pairs did not. Rather, pairs used either a turn-taking or a minimal coordination heuristic throughout the whole experiment, allowing them to ignore the alternations of perceptual features even when both colour and form alternated at the same rate. This would also explain why ambiguous sequences did not pose an additional planning problem for pairs. As pairs were not guided by perceptual features alone in their task distributions, the chosen heuristic could help them decide which perceptual feature to follow in ambiguous sequences.

Importantly, pairs were immediately able to come up with a successful task distribution strategy in the present experiment. In fact, they were even slightly faster than individuals who adopted a certain strategy a little bit later during the first block of trials. Unlike in Experiment 1, pairs did not have higher task distribution errors than individuals.

Experiment 3

In this experiment, we investigated further how task difficulty affects the three mechanisms of mentalizing, heuristics use, and perceptual features use in a joint task distribution. In the previous two experiments, the three mechanisms contributed to task distribution in different ways. Mentalizing was involved when task mappings were ambiguous and when a partner was involved (see Experiment 1). Heuristics minimized the need for mentalizing in Experiment 2. Perceptual features contributed to task distribution supporting particular heuristics (see Experiment 2) or provided a basis for task distribution when heuristics could not be applied (see Experiment 1). In Experiment 3 we asked how the need to find an equal distribution for each type of subtask affects the use of different mechanisms for task distribution.

One group of participants was instructed to not only achieve a fair distribution in terms of the number of actions performed by each partner, but to also make sure that each partner performed each type of response equally often. This captures the complexity of task distribution problems where team members must plan and keep track not only of how often each team members acts, but how often they perform a specific task. The items in the sequences used for this experiment were all randomly arranged and did not support the turn-taking or the minimal coordination heuristic.

If implementing the additional constraint on the type of actions needed in a task distribution requires mentalizing, this should generally result in a longer planning time. The need to equate the number of each response type should result in an increased effort to explicitly plan each of one's own actions as well as the actions of one's partner in the upcoming sequence. However, if mentalizing can potentially be minimized using heuristics or perceptual features, thereby reducing the planning difficulty associated with task distribution, heuristics or perceptual features should be used to avoid additional costs of mentalizing. If perceptual features are used to distribute the task, the alternation of perceptual features of the items in the sequence should determine who takes care of which actions.

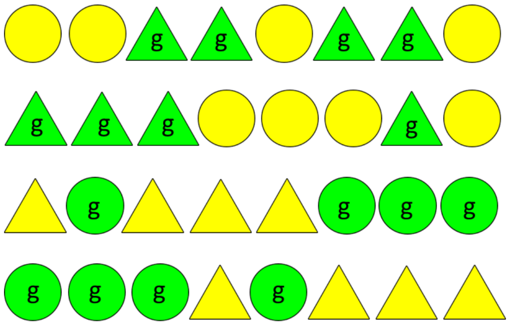
Method

Participants. Ninety-two participants (58 females, age range 18 – 39 years) were recruited through the university's SONA system and a student organisation. Forty-six participants were assigned to the condition with no additional constraints on task distribution, performing the task in 23 pairs. Another 46 participants were assigned to the condition with additional constraints, performing the task in 23 pairs. Participants were reimbursed with vouchers worth 1500 Hungarian forints or 1500 Hungarian forints in cash. All participants reported normal colour vision and had at least conversational skills in English. This experimental study was approved by the United Ethical Review Committee for Research in Psychology, Hungary.

Material and Apparatus. Material and apparatus were the same as in Experiment 1 and Experiment 2 except for the type of sequences used. The items in the sequences for Experiment 3 were arranged randomly. A total of 108 such sequences was generated from which 18 were randomly picked by E-prime each time the experiment was run. All sequences consisted of eight items that required eight separate responses. Each sequence comprised two out of the four elements, yellow triangles and green circles, or yellow circles and green triangles.

Figure 15

Example Stimuli Sequences Used in Experiment 3



Note. For purpose of contrast on monochrome displays, items labelled with ‘g’ are green in colour; items not labelled are yellow in colour. No labels were used in the actual experiment.

Procedure. The procedure was the same as in Experiment 2 except for the task instructions. In the condition with additional constraints on action types in task distribution, both individuals in a pair were instructed to perform the colour and form task equally often in each trial. In the condition with no additional constraints, i.e., just an action frequency constraint as with the previous experiments, the instructions were the same as in Experiment 2. Participants had to respond to the whole sequence of items such that both individuals in a pair responded equally often. If participants violated these instructions, a distribution error feedback appeared after the trial. This feedback listed the number of responses made per player and reminded participants that “Each player should respond 4 times” (in the condition with an action frequency constraint) or that “Each player should do both the colour and form task equally often” (in the condition with an action type constraint).

The 18 sequences were presented in 18 blocks with four repetitions of the same sequence per block. This resulted in 72 trials total. The main experiment took an average of 22.0 minutes in the group with just an action constraint on frequency and 29.7 minutes in the group with an additional action constraint on action types.

Results

We analysed the same variables as in the previous two experiments. One pair from each Condition (Action Constraint: Freq.; Action Constraint: Type) was excluded because response errors deviated more than three standard deviations from the mean in their respective groups. Three pairs from the Action Constraint: Frequency (AC: Freq.) condition and one pair from the Action Constraint: Type (AC: Type) condition were excluded because they reported after the experiment that they did not understand the instructions. From the correct responses across all sequences, groups in both conditions showed no clear preference for performing the colour or form task. AC: Freq. pairs and AC: Type pairs performed the form task at 51.8% and 50.1% respectively.

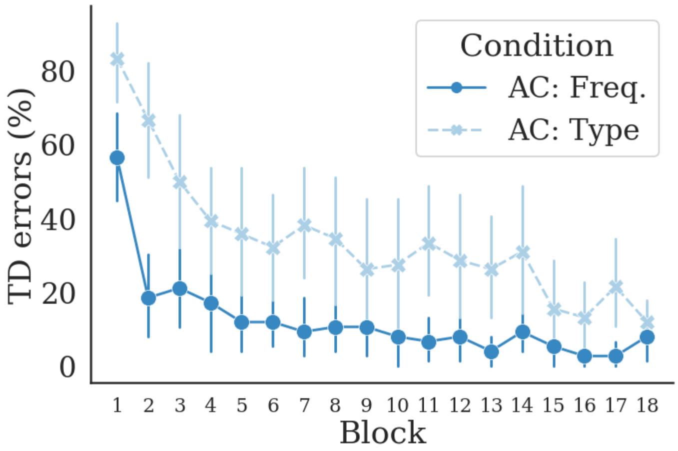
Response Errors. There was no significant effect of Condition, *t*(30.12) = -0.77, *p* = .447, *d* = -0.24 (corrected for unequal variances). Pairs in the AC: Type condition had an error rate of 6.7% (*SD* = 8.0%) and pairs in the AC: Freq. condition had an error rate of 5.2% (*SD* = 4.0%).

Task Distribution Errors. Pairs in the AC: Type condition (*M* = 34.1%, *SD* = 26.4%) made more task distribution errors than pairs in the AC: Freq. condition (*M* = 12.3%, *SD* = 9.7%), *t*(25.83) = -3.54, *p* = .002, *d* = -1.10 (corrected for unequal variances). A Greenhouse-Geisser corrected mixed 2-way ANOVA with the between-subject factor Condition (AC: Freq., AC: Type) and the within-subject factor Block (1 – 18) revealed that the proportion of task distribution errors significantly decreased over time, *F*(8.13, 309.08) =

19.05, $p < .001$, $\eta_p^2 = .33$. The interaction was also significant, $F(8.13, 309.08) = 1.97$, $p = .048$, $\eta_p^2 = .05$. The rate of task distribution errors became more similar across groups in later blocks.

Figure 16

Mean Proportion of Task Distribution Errors Across All 18 Blocks



Note. Error bars are 95% confidence intervals.

Preview Time. There was a significant main effect of Condition, $t(32.85) = -2.21$, $p = .034$, $d = -0.69$ (corrected for unequal variances). AC: Type pairs had longer preview times (M = 4562ms, SD = 1782ms) than AC: Freq. pairs (M = 3552ms, SD = 1047ms).

An additional Greenhouse-Geisser corrected mixed 2-way ANOVA with the between-subject factor Condition (AC: Freq., AC: Type) and the within-subject factor Block (1-18) showed a significant effect of Block on PT, $F(5.29, 200.96) = 24.30$, $p < .001$, $\eta_p^2 = .39$, but no interaction between Block and Condition, $F(5.29, 200.96) = 0.64$, $p = .675$, $\eta_p^2 = .02$. Pairs performing the task under action type constraints took an average PT of 10,437ms (SD = 5401ms) at the first block and 3363ms (SD = 1504ms) at the last block. Pairs performing the task under action frequency constraints took an average PT of 8170ms (SD = 3129ms) at the first block and 2621ms (SD = 1402ms) at the last block.

Reaction Time. There was no significant difference in reaction time between conditions, $t(38) = -1.61$, $p = .115$, $d = -0.51$. AC: Type pairs had a mean RT of 560ms (*SD* = 227ms) and AC: Freq. pairs had a mean RT of 455ms (*SD* = 175ms). A Greenhouse-Geisser corrected mixed ANOVA with the between-subject factor Condition (AC: Freq., AC: Type) and the within-subject factor Block (1-18) revealed a significant block effect on RT, $F(4.43, 168.49) = 13.23$, $p < .001$, $\eta_p^2 = .26$. The interaction effect of Block and Condition was not significant, $F(4.43, 168.49) = 0.72$, $p = .592$, $\eta_p^2 = .02$. Pairs performing the task under action type constraints took an average RT of 834ms (*SD* = 451ms) at the first block and 457ms (*SD* = 231ms) at the last block. Pairs performing the task under action frequency constraints took an average RT of 744ms (*SD* = 365ms) at the first block and 342ms (*SD* = 152ms) at the last block.

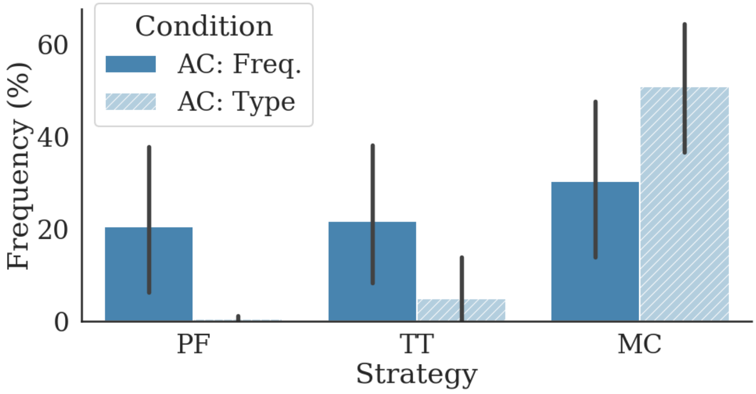
Switches per Sequence and Strategy Use. On average, AC: Freq. pairs ($M = 3.64$, $SD = 2.07$) switched more often than AC: Type pairs ($M = 2.23$, $SD = 1.25$), resulting in a significant group difference, $t(28.92) = 2.57$, $p = .016$, $d = 0.82$ (corrected for unequal variances). This provides a first indication that AC: Type pairs preferably used a minimal coordination strategy.

To further analyse strategy use, we coded for different switching behaviours between partners. Task distributions where switches between partners followed the perceptual features of the sequence were assigned to the Perceptual Features (PF) category. Task distributions where partners switched after each item were assigned to the turn-taking category (TT). Task distributions where partners switched in the middle of the sequence were assigned to the minimal coordination category (MC). Any other switching behaviour was considered Null and not a strategy. Using a repeated measures ANOVA with the within-subject factor of Strategies (PF, TT, MC) and the between-subject factor of Condition (AC: Freq., AC: Type), there was a significant difference in how the Strategies were used, $F(2, 76) = 9.04$, $p < .001$,

η_p^2 = .16, and a significant interaction between Strategies and Condition, $F(2, 76) = 4.14$, p = .020, η_p^2 = .07. Condition alone was not a significant factor, $F(1, 38) = 2.95$, $p = .094$, η^2 = .07. A look at Figure 17 shows that AC: Type pairs were using more of MC and hardly any PF strategy. In contrast, while there was a slight preference for MC with the AC: Freq. pairs, there was no big difference between how often they used the three strategies.

Figure 17

Mean Proportion of Strategy Use by Condition



Note. PF: Perceptual Features; TT: Turn-taking; MC: Minimal Coordination. Error bars are 95% confidence intervals.

Table 7

Mean Percentage of Strategy Use by Condition

Strategy	AC: Freq. (*n* = 19)		AC: Type (*n* = 21)	
	M	*SD*	*M*	*SD*
Perceptual Features	20.5	35.8	0.5	1.4
Turn-taking	21.8	35.6	4.9	20.5
Minimal Coordination	30.4	38.4	50.9	34.3

Strategy Discovery and its Effects on Performance. For AC: Freq. pairs, the time to strategy discovery was estimated to be 2.5 blocks (*SD* = 1.7 blocks), and 50.5% (*SD* = 20.9%) of the errors were made in this time. For AC: Type pairs, the block of discovery was at Block 6.6 (*SD* = 4.8 blocks), and 63.4% (*SD* = 23.4%) of the errors were made in this time. This difference between the time to strategy discovery for AC: Freq. and AC: Type pairs was significant, $t(25.7) = -3.61$, $p = .001$, $d = -1.12$ (corrected for unequal variances). There was no significant difference between groups for the error rates, $t(38) = -1.83$, $p = .075$, $d = -0.58$.

As before, we checked whether not using a successful strategy increased task distribution errors and whether using a successful strategy decreased preview times. While the random sequences used in this experiment allowed us to distinguish between the use of perceptual features from heuristics, we were still not able to run our statistical analyses at the level of each individual strategy. This is because pairs could use any of these strategies at any time, and this led to an uneven frequency distribution across cells (see Table 8 and Table 9). Accordingly, a 'strategy'/'no strategy' distinction was used for the following analyses.

The frequency of 'no strategy' trials was 27.3% (*SD* = 26.7%) for AC: Freq. pairs and 43.7% (*SD* = 33.1%) for AC: Type pairs. This difference was not significant, $t(37.5) = -1.74$, $p = .091$, $d = -0.55$ (corrected for unequal variances). A higher percentage of 'no strategy' trials was associated with a larger number of task distribution errors in AC: Freq. pairs, $r(17) = .56$, $p = .013$, and also for AC: Type pairs, $r(19) = .55$, $p = .010$. For AC: Type pairs, it was possible to use a strategy and still make task distribution errors, *M* = 8.8%, *SD* = 6.6%. The correlation for use of strategy and task distribution errors was not significant for AC: Type pairs, $r(18) = .38$, $p = .102$.

AC: Freq. pairs had significantly longer preview times in 'no strategy' trials (*M* = 5649ms, *SD* = 2757ms) than in 'strategy' trials (*M* = 3201ms, *SD* = 1030ms), $t(17) = 4.22$, $p < .001$, $d = 1.00$. AC: Type pairs also had significantly longer preview times in 'no strategy' trials (*M* = 6477ms, *SD* = 3771ms) than in 'strategy' trials (*M* = 4092ms, *SD* = 1778ms), $t(19) = 3.53$, $p = .002$, $d = 0.79$. 'No strategy' trials were significantly correlated with PT for AC: Freq. pairs, $r(17) = -.49$, $p = .034$, and also for AC: Type pairs, $r(19) = -.47$, $p = .034$.

There were no significant correlations for use of any strategy and PT for AC: Freq. pairs and AC: Type pairs.

Table 8

AC: Freq. Subset of Task Distribution Errors and PT Means Per Strategy

Strategy	*n*	Freq.	Occurrence	TD errors	PT (ms)
Minimal Coordination	10	57.8%	73.7%	0%	3073
Turn-taking	10	41.4%	60.5%	0%	3347
Perceptual Features	10	39.0%	59.7%	0%	3775

Note. Occurrence = how often a strategy was used within a block

Table 9

AC: Type Subset of Task Distribution Errors and PT Means Per Strategy

Strategy	*n*	Freq.	Occurrence	TD errors	PT (ms)
Minimal Coordination	18	59.3%	79.3%	9.2%	4239
Turn-taking	6	17.1%	36.6%	1.2%	5512
Perceptual Features	4	2.78%	43.8%	0.7%	7513

Note. Occurrence = how often a strategy was used within a block

Discussion

Experiment 3 asked how increasing task distribution difficulty by adding additional constraints on action type affects the use of different mechanisms for joint task distribution. In line with our prediction that additional constraints on action type should require more mentalizing, the results showed that preview times increased when action type constraints were added. The longer preview times in pairs indicate that action type constraints required pairs to think harder about the partner's planning and upcoming actions.

Secondly, we predicted that planning difficulty can be reduced with the use of heuristics or perceptual features. Although we found no group difference in how often pairs used or did not use a strategy, we see an interesting difference with regards to which strategies were preferred. When planning for a task distribution with action frequency constraints, pairs made use of both perceptual features and the turn-taking and minimal coordination heuristics, a finding that replicated the results from the previous two experiments. When planning for a task distribution with action type constraints however, we find that pairs had a very strong and specific preference for the minimal coordination heuristic. The preferred use of this heuristic in the face of increased difficulty of task distribution may reflect attempts to minimise the number of turns between partners. This could free up processes and redirect resources to be used for monitoring errors in performance. Unfortunately, it is difficult to make more specific inferences about each of the strategies. This is because pairs could use any of these strategies at any time in this experiment, resulting in an uneven distribution of frequencies across conditions. A bigger sample should help provide a better understanding of how the different strategies improve performance.

In the current experiment, task difficulty was increased by adding additional constraints on the type of actions needed in a task distribution. This manipulation of task difficulty was effective because it took participants much longer to establish successful task distribution when additional constraints on action types were present. It remains to be explored how other aspects of task difficulty affect the use of mentalizing, heuristics, and perceptual features for task distribution.

General Discussion

The goal of this study was to identify the cognitive processes that enable joint action partners to plan a fair task distribution. Three candidate mechanisms were proposed, namely mentalizing, heuristics, and perceptual features. To examine which of these three mechanisms support achieving fair task distributions, we designed a new experimental task that allowed us to assess both the planning and performance stages of a task distribution. In three experiments, we found that heuristics drove task distribution during joint action while perceptual features chiefly determined task distribution during individual action. Mentalizing was mostly used to deal with action type constraints and ambiguities regarding the partner's actions or the task itself.

Supporting a role for mentalizing in achieving fair task distributions, Experiment 1 demonstrated that planning times increased when there was a need to distribute tasks between partners. Compared to individuals who needed only to mentally account for themselves, pairs had to factor in the planning of their partners. This additional planning requirement led to a longer planning time with pairs in the first experiment. When the task involved a higher degree of ambiguity, additional planning was required. This provides a clear indication that the increase in planning time was related to thinking about the partner's planning of the upcoming joint performance.

The need for mentalizing should also increase when the difficulty of task distribution increases. When action type constraints on task distribution were added in the third experiment, planning required more time, indicating that it became more difficult. The additional constraints on action types required each individual in a pair to come up with an action plan for themselves and their partners that satisfied the specific conditions for a fair task distribution. Despite the longer planning times, this was quite difficult to achieve for pairs, as illustrated by the high amount of task distribution errors.

Planning difficult task distributions likely involves assessing which task distribution strategies may work best and assessing how to best agree on such a strategy. However, planning is no guarantee for success. Indeed, in all of the present experiments, long planning intervals were often followed by errors in task distribution, or joint performances that did not have a recognizable task distribution strategy. Thus, there is a possibility that mentalizing is only used if there are problems with finding an easy way of distributing tasks.

Task distribution heuristics such as turn taking or minimal coordination, that is, minimizing the number of turns, provide an easy and general way to fairly distribute tasks if applicable. They can potentially be applied to any joint task that involves a sequence of similar actions. The current results provide clear evidence that, although such heuristic may be general-purpose in principle, they are much more frequently used in joint action than in individual action. In the first two experiments where task distribution was compared between pairs and individuals, we found that the use of task distribution heuristics was quite specific to the social contexts. The second experiment demonstrated that pairs gained a planning advantage over individuals when heuristics use was advantageous because perceptual features of a sequence were ambiguous with respect to task distribution.

Considering that heuristics use seems specific to the social context, an interesting question for future research is if joint action partners use one heuristic as a default (e.g., minimal coordination) and only consider other heuristics if problems occur. Alternatively, they may immediately try to apply heuristics that have the highest likelihood of ensuring a fair task distribution for a particular task. Finally, pairs were less likely than individuals to use perceptual features to achieve a fair task distribution While individuals preferred use of perceptual features, whenever possible, pairs used perceptual features to anchor turn-taking or minimal coordination heuristics. An exception is the third experiment, where in the easier condition without action type constraints on task distribution, perceptual features were used almost as often as either of the heuristics. A possible explanation for this finding is that here, participants did not encounter sequences where perceptual features were ambiguous (as in the ambiguous features condition of Experiment 2) or worked against an efficient task distribution (as in the alternate by 2 condition in Experiment 1). It remains to be seen whether joint action partners generally avoid the use of perceptual features because it requires establishing an agreement on how features relate to individual actors. Alternatively, joint action partners may be more prone to make use of perceptual features in task distribution if agreement is easier to establish, e.g., through verbal communication, than in the present task.

Taken together, our results highlight that ensuring fairness in joint action is not only a matter of deciding between different options that imply different rewards for the individuals involved. Rather, to ensure fairness of task distribution, humans recruit a whole variety of processes that reach from thinking about a partner's plans and contributions to dedicated heuristics and use of perceptual characteristics of the events and objects to be acted upon. Further systematic study of these processes will enhance our understanding of humans' capabilities to fairly and effectively distribute tasks during joint action and the limits of these capabilities. Organizational justice research has revealed, for example, that the fairness of a procedure is as important as the fairness of an outcome (Cohen-Charash & Spector, 2001; Folger & Konovsky, 1989). While this current study has focused on the fairness of outcomes in terms of the costs incurred by each partner (Deutsch, 1975), fairness of procedure would be another important factor when planning for a task distribution. Such an understanding would have practical implications in helping explain sources of conflicts between joint action partners. It could also help with the design of robots that are able to swiftly perform joint actions with humans.

Chapter 2: Procedural and Distributive Fairness in a Joint Task Distribution

Within human cultures where cooperation makes up so much of everyday life (Tomasello, 2009a), there is a strong motivation for most people to be fair, even when being fair provides no direct benefits (Fehr & Fischbacher, 2003; Fehr & Schmidt, 2006). Indeed, it would seem that people are cooperative by default, and only acting in more self-beneficial ways when allowed to deliberate (Rand, 2016; Rand et al., 2014). When under a high cognitive load, for example, people on average contributed half of their personal endowment in a public goods game (Døssing et al., 2017), demonstrating a high degree of pro-sociality. This is in direct contrast to what the classic *homo economicus* would be expected to do: to selfishly keep all of the endowment for herself in order to maximise her own gains (Stout, 2008). Fairness and cooperation in previous research, however, mostly reflect findings on decisions made about resource distribution in economic games. Fairness outside of these games can be much more than simply giving up the arithmetic half of one's personal endowment. Depending on the type of relationships involved (Barrett-Howard & Tyler, 1986), the gravity of the situation (Keren & Teigen, 2010), or simply on whether one's conception of fairness is based on the values of need, ability, efforts, or accomplishments (Deutsch, 1975), fairness can be approached differently.

Importantly, different types of fairness have been distinguished in previous research. First, one can ensure fairness through the distribution of resources between partners. This is the focus of much of the literature on fairness and can be referred to as distributive fairness (Cook & Hegtvedt, 1983). The second approach is termed procedural fairness and concentrates on the procedure by which the distribution of resources was made (Konovsky, 2000). In this case, a fair procedure would be one which provides an equal opportunity to all the partners involved. In terms of planning a fair task distribution between partners, this would mean thinking about a procedure that ensures each partner is fairly represented and that the resources are assigned to each partner in a fair manner. Studies in organizational research have found that both procedural fairness and distributive fairness contribute significantly to the overall perception of fairness (Ferguson, Ellen, & Bearden, 2014; Greenberg, 1986). Importantly, while a fair procedure can sometimes lead to a fair distribution of resources, a fair distribution may not necessarily result from fair procedures (Cook & Hegtvedt, 1983).

Additionally, as with most daily joint tasks like household chores (Thomson, 2007) or group projects (Aggarwal & O'Brien, 2008), fairness in joint action is often less about a fair procedure ensuring a fair distribution of resources than about a fair procedure ensuring a fair task distribution where each partner contributes more or less the same amount of effort. Individuals looking to ensure fairness on a joint task would have to consider not only the fairness of a procedure in their planning process but also if a procedure would lead to a fair distribution of effort. This study presents a first attempt at discerning and understanding how concerns for procedural fairness and distributive fairness contribute to the planning of task distributions in joint performance. We focused on the question of a fair distribution of effort and asked how distributive fairness affects the use of a fair procedure in task distribution planning.

Procedural Fairness in Task Distribution

Procedural fairness refers to the fairness of a process by which allocations of resources are determined (Konovsky, 2000). Recent studies have found that children as young as three years old can recognize and choose a fair procedure over one that would otherwise privilege them at the expense of others (Grocke et al., 2019). In this study, children chose a wheel of fortune that gave everyone an equal chance over a biased wheel that ensured only one child won. Using a similarly biased wheel of fortune, another study showed that eight year old children preferred throwing an additional resource away rather than using the partial procedure to assign it to one partner only (Shaw & Olson, 2014).

A fair procedure that is commonly found across many real-world settings is turn-taking. In environments with a common pool resource (Ostrom, 1990), fishermen regulate access to prime fishing spots by taking turns (Berkes, 1986). Turn-taking is also used very much in the debate arena, where turn-taking is formally enforced to ensure that each side gets exactly the same amount of time to speak. Outside of debates and in everyday conversations around the world, turn-taking would generally ensure that everyone gets an opportunity to speak (Stivers et al., 2009). Turn-taking also seems to occur from a very young age, with infants naturally being able to take turns and engage in proto-conversations with their caretakers (Levinson, 2016). Additionally, when successful collaboration on a joint task led to a reward which only one partner can access, five-year-old children were capable of using turn-taking to ensure stable cooperation and a fair distribution of rewards over time (Melis et al., 2016). On its own, turn-taking is also a fair procedure that is highly flexible (Leo, 2017). In the event where one partner has trouble fulfilling their obligations, for example, partners using turn-taking can easily switch turns without disrupting the existing arrangement.

There are limitations to turn-taking, however. From possession of public to private information about payoff structures (Kaplan & Ruffle, 2012), to differing costs of contributions between partners (Riyanto & Roy, 2019), there are often asymmetries inherent in a social context that can engender unfair outcomes even with the use of a fair procedure such as turn-taking.

Distributive Fairness in Task Distribution

In the broader societal context, distributive justice can take on different values depending on the organization and culture (Alesina & Angeletos, 2005; Deutsch, 1975; Kim

& Leung, 2007). In organizations focused on economic productivity, as has been mostly the focus of organizational justice research, the ratios of input and output are usually the key factor in determining distributive fairness (Adams, 1965; Deutsch, 1975). Fairness, according to this equity principle, would be determined by the proportion of a person's rewards and costs in relation to the amount of assets invested. Pay satisfaction, for example, would be one area where distributive justice is most relevant (Cohen-Charash & Spector, 2001; Folger & Konovsky, 1989). Where employees are dissatisfied and perceive a lack of distributive justice, they may try to "get even" and engage in retaliatory behaviour (Skarlicki & Folger, 1997), such as pilfering from the company (Greenberg, 1990).

Outside of rewards and resources, distributive fairness is also a relevant concern when it comes to chores or other activities that are normally ascribed a negative utility (Aziz, Caragiannis, Igarashi, & Walsh, 2019). One current example is the distribution of costs regarding reducing global CO_2 emissions. In a study by Carlsson and colleagues (2013), ordinary citizens from the largest two CO_2-emitting countries of China and the United States reported a preference for the distribution rule that cost their countries the least. At the domestic level, the number of household chores that are completed by wife and husband has been found to be related to marital satisfaction for both partners and to rates of divorce for women (Frisco & Williams, 2003). For dual-income households in the United States, men reported a distribution of household chores where they did just half or under half as unfair while women found it unfair when they had to complete all or close to all of the housework. Between siblings, what is considered a fair distribution of housework appears to be simpler. When children from eight to sixteen years were asked to judge various distribution of household chores for fairness, they were more likely to view a distribution of household chores based on the equality principle as fairer than divisions based on equity or need (Thomson, 2007). In this study, the distribution based on the equity principle meant that children who were able to earn their own keep outside of the house and not need an allowance were given a reduction in chores to do. Distribution based on the need principle meant that lesser chores were given to children who had personal obligations to fulfil at school. These distributions were disfavoured over the one based on the equality principle, where household chores were equally distributed among the children, regardless.

Clearly, different principles can be used to determine the fairness of a distribution. Where tasks are easily divisible and comprise equal-sized units, distributive fairness can be achieved readily via arithmetic calculations or the use of fair procedures like turn-taking. Most tasks in everyday life, however, are a lot more complex and do not lend themselves to a fair distribution between partners as easily. These tasks, like housework especially, are not only commonly unrewarding or unappealing to carry out but can also lead to serious and unhappy consequences when distributive fairness is not achieved. Naturally, when planning for such a task distribution between partners, distributive fairness is an important factor to consider.

The Present Study

As a first attempt to understand how achieving distributive fairness in the face of a fair procedure affects task distribution in joint action partners, we modified the existing experimental design from the previous study to allow for a fair procedure to lead to an unfair distribution of effort. Previously, we found that pairs converged quickly on the social heuristics of turn-taking and minimal coordination when planning for a fair task distribution. Turn-taking is the switching between partners after each subtask while minimal coordination is the strategy of minimizing the number of turns necessary between partners to complete the task. For minimal coordination on a task comprising eight subtasks, pairs would switch after half of the task was done. This means that one partner would start first to complete the first four subtasks, after which the other partner completes the last four subtasks. In the previous task design, using either of the turn-taking or minimal coordination heuristics served as fair procedures that led to a fair distribution of effort. Specifically, using either of these strategies meant that each partner completed four subtasks in a task comprising eight sequential subtasks.

For this current study, an effort asymmetry was introduced such that one subtask required a greater effort than the other to complete. This meant that while using turn-taking and minimal coordination would ensure that both partners were represented fairly in the task, the effort required for each partner may or may not be equal. Additionally, because no resources or rewards were used in this study, there was no compensation that could match the amount of effort contributed to the task. The number of subtasks completed did not depend on whether a subtask required a big or small effort to complete; the number of subtasks completed was the same throughout. This meant that it was not possible for a distribution on this task to be fair using the principle of equity. Rather, a fair distribution would be one based on the principle of equality, where each partner contributed an equal amount of effort to the task.

General Predictions

If the lack of distributive fairness in terms of effort does not preclude the use of a fair procedure when planning a task distribution, fair procedures like the turn-taking heuristic and the minimal coordination heuristic should be used even if they lead to an unequal distribution of effort in a joint task. If distributive fairness in terms of effort is important and guides the use of a fair procedure when planning a task distribution, distribution should follow a strategy that ensures an equal distribution of effort between partners. If distributive fairness matters, the presence of an effort asymmetry in the task should also make planning for a fair task distribution more difficult, thereby increasing the planning time needed.

Experiment 1

To determine how distributive fairness guides the use of fair procedures in task distribution planning, it is necessary to first set up a situation where the fairness of procedure and fairness of distribution are independent. In order to do this, we introduced an effort asymmetry in a task sequence such that by using a fair procedure like turn-taking or minimal coordination, one partner would have to invest a larger effort in the overall task. Effort in this task was operationalized as the number of key presses required in response to each item of a task sequence. For example, the subtask of reacting to a green target would require one button press whereas the subtask of reacting to a red target would require pressing the same button four times to complete. Accordingly, distributive fairness means that within the overall task, both partners press the button an equal number of times. Where one partner pressed the button more than the other, this was considered an unequal effort distribution.

If fair procedures are used when planning for a task distribution, even if they do not ensure distributive fairness in terms of effort, turn-taking and minimal coordination heuristics should still be used even when they lead to an unequal distribution where one partner would have put in more effort than the other. This should result in a greater number of unequal effort distributions than if distributive fairness was a precondition for the use of a fair procedure.

If distributive fairness guides the use of a fair procedure when planning for a task distribution, we predict that turn-taking and minimal coordination heuristics should be used only when they lead to a fair distribution of effort. Where fair procedures do not ensure distributive fairness, partners should want to use a more carefully calibrated procedure that would result in each partner contributing an equal amount of effort to the task. Accordingly, if distributive fairness is important when planning a task distribution, effort asymmetry across the subtasks should generally increase coordination difficulty and lead to a longer planning time. Each individual in a pair would need to explicitly think about a procedure and check that it will ensure a fair distribution of effort between partners. This means that for every potential strategy, it would be necessary to first calculate whether the total amount of effort required for each partner is equal. This advanced mental computation should occur most when both turn-taking and minimal coordination heuristics do not lead to an equal distribution of effort. This advanced mental computation should also be larger for pairs than for individuals distributing the tasks between their two hands. Unlike individuals who have full flexibility in assigning tasks to effectors (Knoblich & Jordan, 2003), pairs would need to consider what actions their partners are planning in order to achieve distributive fairness.

While procedural fairness and distributive fairness have mostly been studied in the social context, it is an open question whether procedure and the equality of the resulting distribution play a role in distributing effort within individuals. Individuals distributing a task between their two hands, for example, might be concerned to not overtire one hand over the other. In the previously reported experiments in Chapter 1, individuals distributing a task between their two hands relied very much on the perceptual features of the task. With a task comprising an equal number of green and red items, for example, individuals would distribute the task such that one hand is responsible for the green items and the other hand for the red items. Without an effort asymmetry present, using perceptual features for a task distribution clearly leads to an equal distribution of effort between hands. With an effort asymmetry present however, such that responding to red requires more effort than responding to green, for example, the resulting distribution of using perceptual features would lead to one hand being used more than the other. If achieving equality in terms of energy expenditure between two hands is important for individual task distribution, the presence of an effort asymmetry in the task should lead to greater planning difficulty and result in a longer planning time.

Assuming that achieving an equal distribution of effort is important when planning for an individual task distribution, the next question is how this planning process for individuals compares to planning a fair task distribution in terms of effort distribution for pairs. In the previous study (Chapter 1: The Role of Mentalizing, Social Heuristics, and Perceptual Task Features), pairs planning for a task distribution needed to mentalize more and took a longer planning time than individuals when different task rules could be applied (Experiment 1). When social heuristics like turn-taking and minimal coordination were applicable, however, pairs were able to minimize mentalizing and gain a planning advantage over individuals who relied very much on the perceptual features of a task (Experiment 2).

Accordingly, where turn-taking and minimal coordination do not lead to an equal distribution of effort, planning should be more difficult for pairs than for individuals. While partners have to consider what the other person is planning when choosing from the multiple strategies possible, individuals need only decide on one that would ensure an equal distribution of effort without factoring in what anybody else thinks. Thus, we should expect to see pairs taking a longer planning time than individuals.

Method

Participants. Sixty-nine participants (53 females, age range 18 – 37 years) were recruited through the university's SONA system and a student organization. Twenty-five participants were assigned to the individual condition and 44 participants were assigned to the joint condition, performing the task in 22 pairs. Participants were reimbursed with vouchers worth 1500 Hungarian forints or 1500 Hungarian forints in cash. All participants reported at least conversational skill in English and normal colour vision. The experimental protocol was approved by the United Ethical Review Committee for Research in Psychology, Hungary.

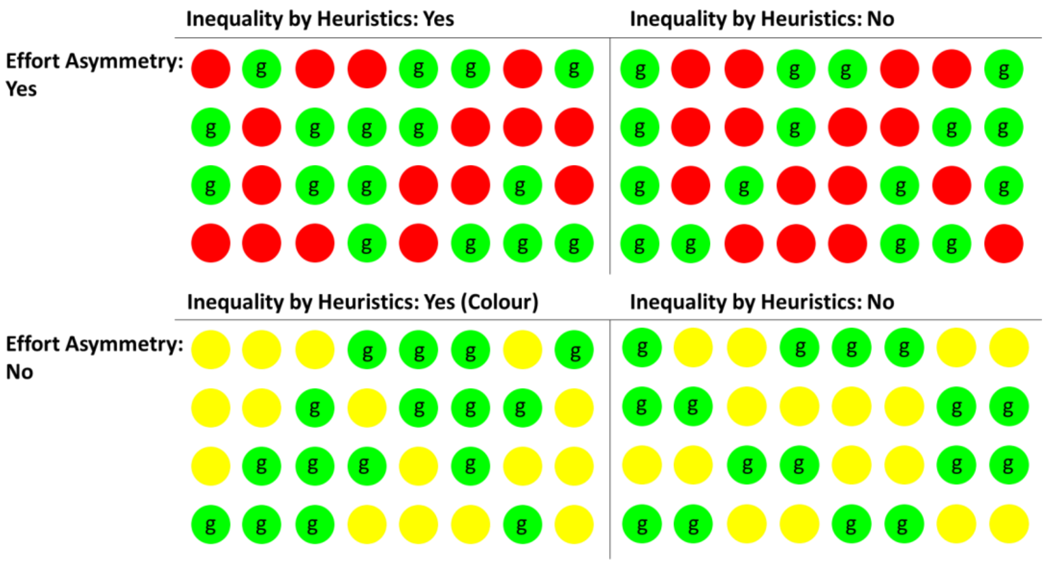
Material and Apparatus. In the individual condition, a 22-inch monitor was set on the table about 50cm away from where the participant was seated. On the table between the monitor and the participant was the controller box with four white circular buttons. Only the two outer buttons were used in the experiment. For the joint condition the setup was duplicated in a separate room (the two individuals in the joint condition could not see each other nor talk to each other). Participants in the solo condition had control over the two buttons used in the experiment. In the joint condition, the two buttons were split between the pairs such that each partner only had access to one of the two allowed buttons throughout the entire experiment. The two monitors in the two rooms were connected to the same computer (Dell Precision, T5610). The experiment was programmed using E-prime 2.0 on the Windows 7.0 Professional operating system.

Figure 18 displays the sixteen different stimulus sequences used in Experiment 1. All sequences consisted of eight items that required eight separate responses. Green and yellow circles each required one press for a valid response. Red circles required four presses of the same button for a valid response. Each sequence consisted of circles in two colours, either green and yellow (sequences with no effort asymmetry), or green and red (sequences with effort asymmetry). The items in these sequences were arranged such that an equal distribution by effort or colour was achievable by use of either the turn-taking and minimal coordination heuristics, or not at all. For all eight sequences with effort asymmetry, an equal distribution would be one where each partner (or each hand, as in the individual condition) responds to a total of two red circles and two green circles. This equal distribution can be achieved easily via use of turn-taking and minimal coordination heuristics for half of these sequences (see the four sequences in the top right cell of Figure 18). For the other half of these sequences (see the four sequences in the top left cell of Figure 18), an equal distribution cannot be achieved via turn-taking and minimal coordination heuristics but only through any other strategy that distributes two red items and two green ones to each partner (or hand). Apart from the turn-taking and minimal coordination heuristics, there are 33 other different strategies possible that would at least ensure equal representation of each partner (or hand). Of these 33 strategies however, none would guarantee an equal distribution of effort throughout all the different sequence types.

Instead, to ensure an equal distribution of effort throughout, pairs would need to rely on a deliberate and careful tracking of who does what in each task sequence to ensure an equal distribution of effort. This might be a strategy where one partner responds to the first two red and green items while the other partner responds to the last two red and green items. Another example strategy might include partners alternating between each other after every red and green item. Using this careful deliberate approach, there are many different strategic variations possible to ensure an equal distribution of effort between partners or hands.

Figure 18

Stimulus Sequences Used in Experiment 1



Note. For purpose of contrast on monochrome displays, items labelled with 'g' are green in colour. Items not labelled in the first row (Effort Asymmetry: Yes) are red in colour while items not labelled in the second row (Effort Asymmetry: No) are yellow in colour. No labels were used in the actual experiment.

Table 10

Projected Percentages of Equal Effort Distributions by Use of Different Strategies

Strategy	For Effort Asymmetry: Yes Sequences	For Effort Asymmetry: No Sequences	For the Entire Experiment
Turn-taking	50%	100%	75%
Minimal Coordination	50%	100%	75%
Perceptual Features	0%	100%	50%

Procedure. After participants signed informed consent, they were introduced to the experimental setup. Participants in the joint condition were randomly assigned to the two experimental rooms. Participants were informed that their task was to respond to sequences of eight items and that a preview of the eight items would be first presented in each trial. The instructions encouraged them to plan in advance how to respond to the whole sequence of items so that both individuals in a pair respond to the same number of items each (in the joint condition) or so that each hand responds to the same number of items (in the individual condition). Participants were instructed to respond to each item in the sequence as quickly as possible after the planning period.

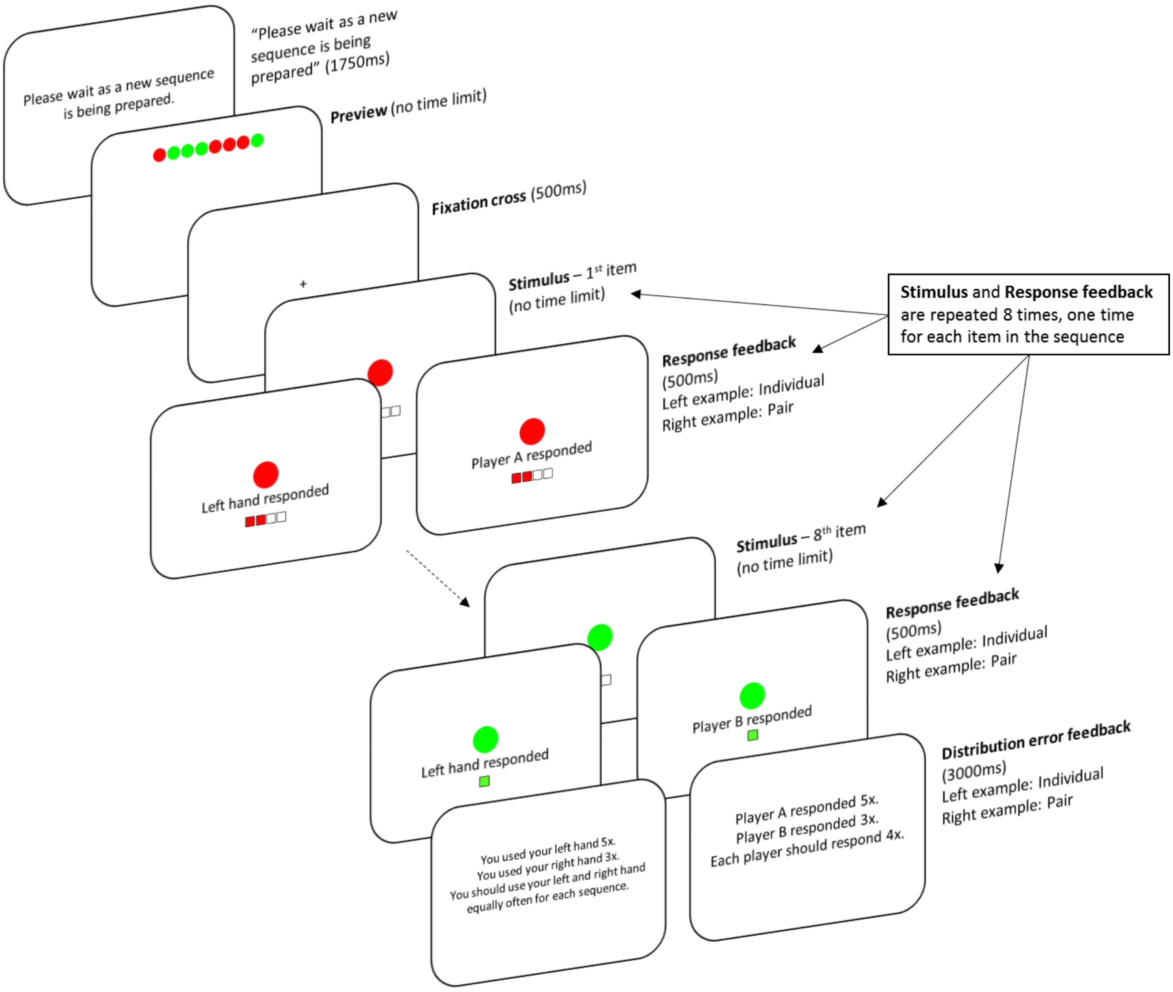
The experiment started with a short familiarization phase where the procedure and the main elements of the task were introduced to the participants. In each trial of the experiment (see Figure 19), participants in the joint condition were first shown a preview of the eight-item sequence. There was no time limit to the preview. Each participant pressed a button when ready to proceed. Only when both participants were ready to proceed did the trial continue. A fixation cross then appeared in the centre of the screen for 500ms. After the fixation cross, each stimulus item in the sequence appeared individually, in the centre of the screen, and remained there until a response was made. The first button press that occurred by a player was counted as that player's response to the item. Depending on who in the pair pressed the button first, a "Player A responded" or "Player B responded" feedback was shown for 500ms. After all the eight items in the sequence had been shown and eight responses had been collected, a feedback appeared for 3000ms if the task distribution between players was unequal (when the number of responses for each player was not equal to four). This task distribution error feedback listed the number of responses made by each player and reminded participants that “Each player should respond 4 times”. Before the preview for the next trial started, participants received a message “Please wait as a new sequence is being prepared” for 1750ms.

The events in each trial were the same in the individual condition with the following exceptions. After each response an individual performed, feedback about the hand they had used was displayed for 500ms. If there was a task distribution error between the two hands, the error feedback listed the number of responses made per hand and reminded participants that “You should use your left and right hand equally often for each sequence” (see Figure 19).

The 16 sequences were presented in 16 blocks with four repetitions of the same sequence per block. Thus, there were 64 trials total. The first four blocks of the experiment comprised two sequences with effort asymmetry and two sequences without effort asymmetry, each randomly picked from the total 16 sequences (see Figure 18). Of these four sequences, one sequence with effort asymmetry and one sequence without effort asymmetry led to an unequal distribution via use of heuristics. The remaining two sequences led to an equal distribution via use of heuristics. The following four blocks similarly comprised the four different sequence types. This arrangement carried on throughout the experiment until all 16 sequences were presented in 16 blocks. The main experiment took an average of 24.1 minutes for individuals and 24.6 minutes for pairs to complete.

Figure 19

Sequence of Events for Each Trial



Results

We analysed response errors, task distribution errors, unequal effort distributions, preview time for each sequence, reaction time to each item in a sequence, and the number of switches made, and strategy used per sequence. One individual was excluded from the analyses due to a technical error. One pair and two individuals were excluded from the analyses because for some sequences, they produced preview times longer than three standard deviations from their own average preview time. For both these individuals, these long preview times (0.83min and 8.6min) were in the later part of the experiments (Block 12 and 14, respectively) where participants were expected to not produce extremely long preview times. While we take the duration of previews to be indicative of how long it takes individuals to plan, it is possible that by this point in the experiment, these participants were likely tired or distracted. For the pair, the long preview time (1.7min) happened in the first block and is likely due to participants still trying to figure out the task instructions rather than thinking about the task distribution. Pairs take an average of 4.2s (*SD* = 1.5s) for the first block. As these preview times were very likely not valid measurements of planning time, these two individuals and one pair were excluded from the statistical analyses entirely.

Another pair and one individual were excluded because their task distribution errors deviated more than three standard deviations from the mean in their respective conditions. Data from a total of 21 individuals and 20 pairs were included in the following statistical analyses. Attempting to achieve a fair task distribution does not necessarily lead to a successful task distribution. Therefore, we included trials in which task distribution by the number of items was not successful in the analyses of preview times, reaction times, and number of switches made.

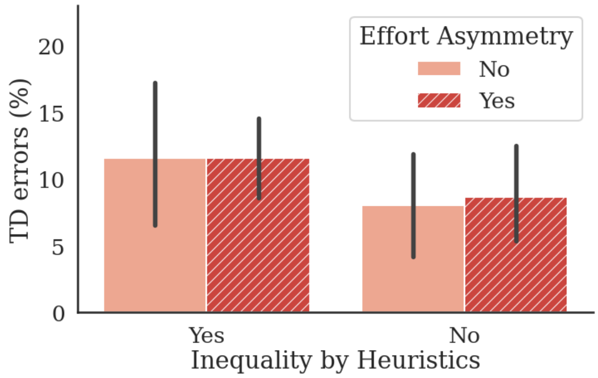
Where not indicated otherwise, results were analysed with a 2 x 2 x 2 mixed ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factors Effort Asymmetry (Yes, No) and Inequality by Heuristics (Yes, No).

Task Distribution Errors. The unequal distribution of eight items, regardless of their effort requirement, was considered a task distribution error. Only a distribution of four items per partner or per hand was considered correct. Individuals made significantly more task distribution errors (*M* = 10.0%, *SD* = 4.9%) than pairs (*M* = 7.0%, *SD* = 5.8%), $F(1, 39) = 5.34$, $p = .026$, $\eta^2 = .12$. There was a significant main effect of Inequality by Heuristics, $F(1, 39) = 4.21$, $p = .047$, $\eta_p^2 = .02$, but not of Effort Asymmetry, $F(1, 39) = 2.58$, $p = .117$, η_p^2

= .01. More task distribution errors were made when an equal distribution by heuristics was not possible (*M* = 10.5%, *SD* = 8.1%) than when it was possible (*M* = 7.8%, *SD* = 8.2%). There were no significant interactions between Condition and Inequality by Heuristics, $F(1, 39) = 0.31$, $p = .581$, $\eta_p^2 < .01$, nor of Condition and Effort Asymmetry, $F(1, 39) = 1.92$, $p = .174$, $\eta_p^2 = .01$. There was, however, a significant effect of Effort Asymmetry on task distribution errors for pairs only, $t(19) = -3.03$, $p = .007$, $d = -0.68$.

Figure 20

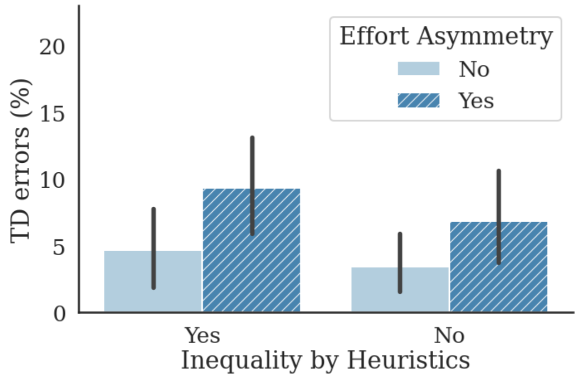
Mean Percentage of Task Distribution Errors Across Factors for Individuals



Note. Error bars are 95% confidence intervals.

Figure 21

Mean Percentage of Task Distribution Errors Across Factors for Pairs

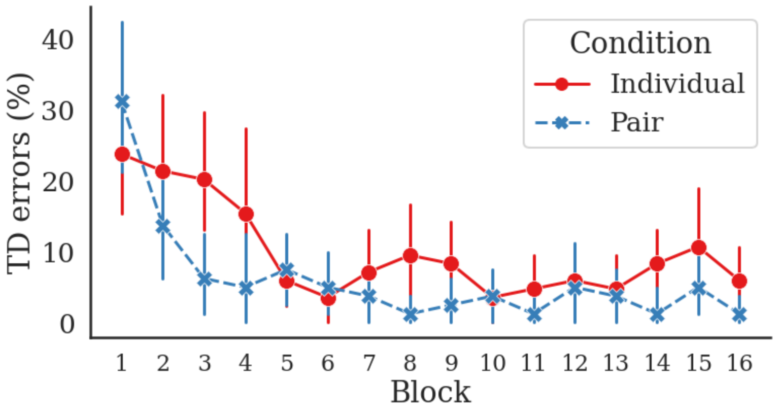


Note. Error bars are 95% confidence intervals.

An additional Greenhouse-Geisser corrected mixed 2-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factor Block (1-16) revealed that the proportion of task distribution errors significantly decreased over time, $F(7.48, 291.80) = 9.31$, $p < .001$, $\eta_p^2 = .16$. The interaction was not significant, $F(7.48, 291.80) = 1.53$, $p = .152$, $\eta_p^2 = .03$.

Figure 22

Mean Percentage of Task Distribution Errors Across All 16 Blocks



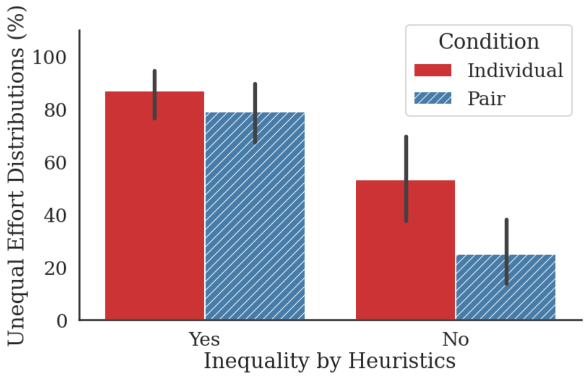
Note. Error bars are 95% confidence intervals.

Unequal Effort Distribution. The unequal distribution of the total number of button presses for a sequence of eight items was considered an unequal effort distribution. In sequences with effort asymmetry, 20 presses of the button total were required for the eight items in each sequence. In this case, an equal distribution of 20 presses would be 10 presses per person or hand. Any other distribution was considered an Unequal Effort Distribution. In sequences without effort asymmetry, the total number of button presses required was the same as the total number of items needed to be distributed. In this case, an unequal distribution of effort would be the same as an unequal distribution of items. These errors are covered by Task Distribution Errors above and will not be included in this section here.

A 2-way ANOVA with Inequality by Heuristics (Yes, No) as the within-subject factor and Condition (Individual, Pair) as the between-subject factor revealed a significant difference in the frequency of unequal effort distributions between individuals and pairs, *F*(1, 39) = 5.97, *p* = .019, η^2 = .13, and also a significant main effect of Inequality by Heuristics, *F*(1, 39) = 66.12, *p* < .001, η_p^2 = .63. Individuals made significantly more unequal effort distributions (*M* = 70.1%, *SD* = 25.4%) than pairs (*M* = 52.0%, *SD* = 21.6%). There were significantly more unequal effort distributions when an equal distribution was not possible by heuristics (*M* = 83.1%, *SD* = 23.9%) than when an equal distribution was possible by heuristics (*M* = 39.5%, *SD* = 36.3%). There was no significant interaction, *F*(1, 39) = 3.59, *p* = .066, η_p^2 = .08.

Figure 23

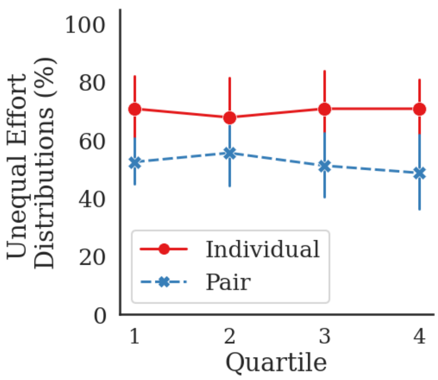
Mean Percentage of Unequal Effort Distributions Across Inequality by Heuristics



Note. Error bars are 95% confidence intervals.

Figure 24

Mean Percentage of Unequal Effort Distributions Across All Quartiles



Note. Error bars are 95% confidence intervals.

As task sequences with effort asymmetry did not occur at every block but in two out of every four blocks for all participants, a Huynh-Feldt corrected mixed 2-way ANOVA was run with the between-subject factor Condition (Individual, Pair) and the within-subject factor Quartiles (1-4). Proportion of unequal effort distributions did not decrease overtime, $F(2.63, 102.55) = 0.11$, $p = .935$, $\eta_p^2 < .01$. There was no significant interaction of Quartiles with Condition either, $F(2.63, 102.55) = 0.62$, $p = .586$, $\eta_p^2 = .02$.

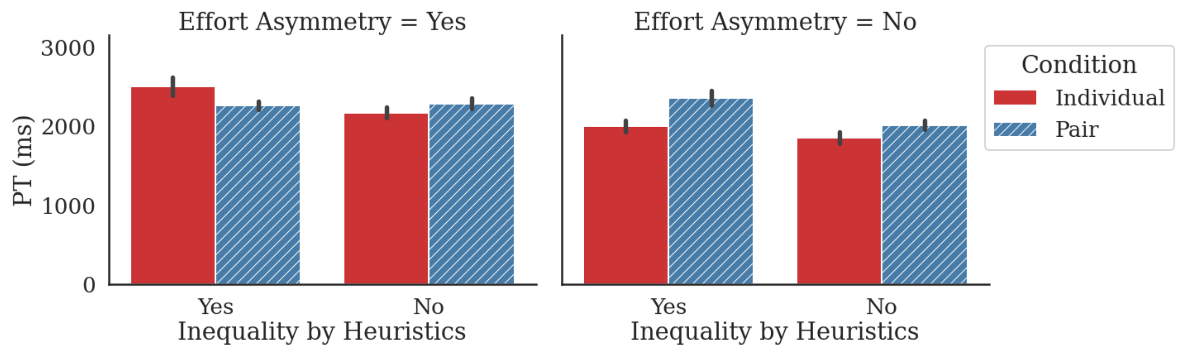
Preview Time. Preview Time (PT) was computed as the time interval from the onset of the preview of the sequence until participants pressed a button to indicate that they were ready to respond to the sequence. Preview times were significantly longer for sequences with effort asymmetry (*M* = 2306ms, *SD* = 990ms) than for sequences with no effort asymmetry (*M* = 2052ms, *SD* = 857ms), $F(1, 39) = 4.86$, $p = .033$, $\eta_p^2 = .02$. Preview times were also significantly longer when heuristics did not ensure equality (*M* = 2325ms, *SD* = 1027ms) than when equality by heuristics was possible (*M* = 2142ms, *SD* = 869ms), $F(1, 39) = 4.99$, $p = .031$, $\eta_p^2 = .01$. There was no effect of Condition, $F(1, 39) = 0.14$, $p = .714$, $\eta_p^2 < .01$, nor an interaction between Effort Asymmetry and Inequality by Heuristics, $F(1, 39) = 0.29$, $p = .595$, $\eta_p^2 < .01$. There was also no interaction between Condition and Effort Asymmetry, $F(1, 39) = 2.03$, $p = .162$, $\eta_p^2 = .01$, nor of Condition and Inequality by Heuristics, $F(1, 39) = 0.20$, $p = .655$, $\eta_p^2 < .01$.

Both pairs and individuals achieved a faster PT over time. A Greenhouse-Geisser corrected mixed ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factor Block (1-16) showed a significant effect of Block on PT, $F(5.15, 200.90) = 14.23$, $p < .001$, $\eta_p^2 = .27$, but no interaction between Block and Condition, $F(5.15, 200.90) = 0.61$, $p = .666$, $\eta_p^2 = .02$. Pairs started out at the first block and ended at the last block with a mean PT of 4207ms (*SD* = 1539ms) and 1948ms (*SD* = 1205ms), respectively.

Individuals started out at the first block and ended at the last block with a mean PT of 4472ms (*SD* = 2833ms) and 1489ms (*SD* = 997ms), respectively.

Figure 25

Mean PT (ms) Across All Factors

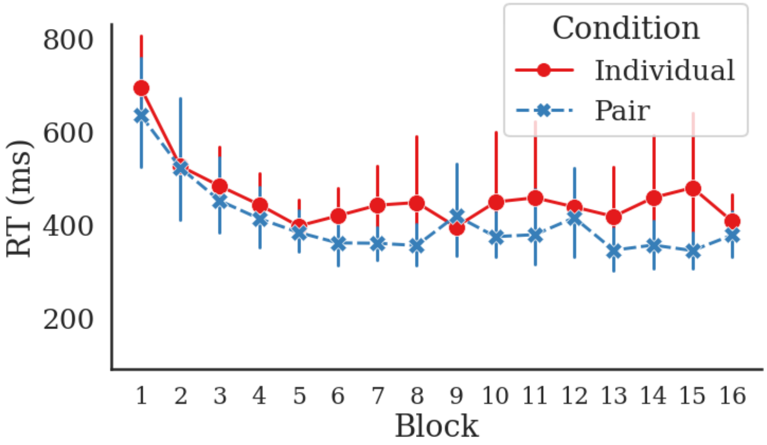


Note. Error bars are 95% confidence intervals.

Reaction Time. Reaction time (RT) was our measure for the average time participants took to respond to each item in a sequence. There were no effects of Effort Asymmetry, $F(1, 39) = 2.14$, $p = .152$, $\eta_p^2 = .05$, nor of Inequality by Heuristics, $F(1, 39) = 0.13$, $p = .725$, $\eta_p^2 < .01$. There was also no significant difference between individuals and pairs, $F(1, 39) = 1.60$, $p = .213$, $\eta^2 = .04$. Using a Greenhouse-Geisser corrected mixed ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factor Block (1-16), we found a significant Block effect on RT, $F(5.34, 208.05) = 8.26$, $p < .001$, $\eta_p^2 = .18$. Pairs started out at the first block and ended at the last block with a mean RT of 635ms (*SD* = 299ms) and 378ms (*SD* = 119ms), respectively. Individuals started out at the first block and ended at the last block with a mean RT of 693ms (*SD* = 247ms) and 408ms (*SD* = 128ms), respectively. There was no significant interaction effect of Block and Condition, $F(5.34, 208.05) = 0.69$, $p = .638$, $\eta_p^2 = .02$.

Figure 26

Mean RT (ms) Across All 16 Blocks

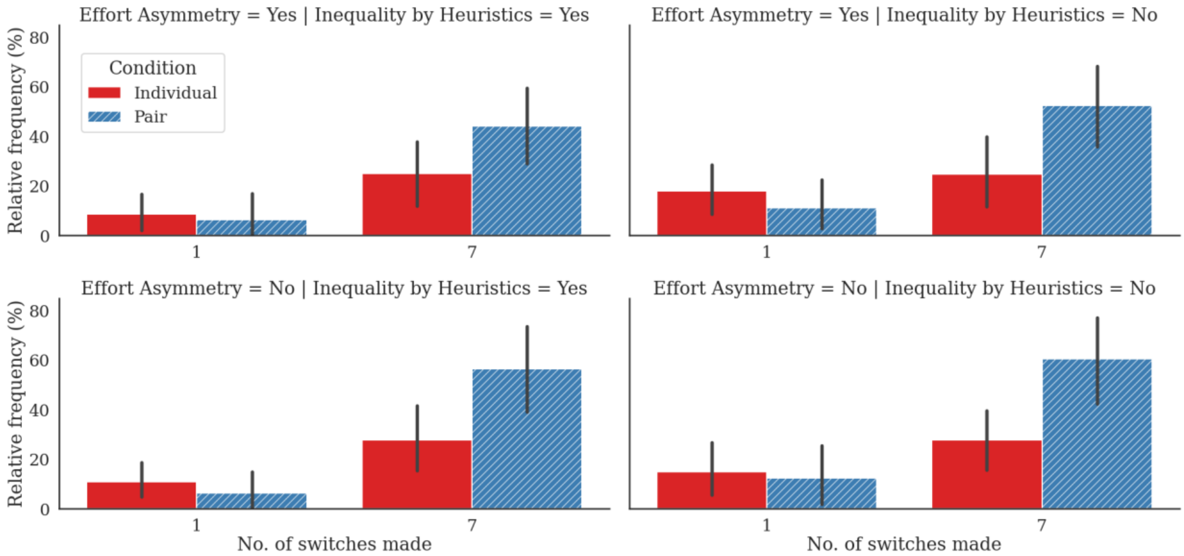


Note. Error bars are 95% confidence intervals.

Switches per Sequence. The number of switches between players or hands provides a direct measure of how participants distributed the task sequences. The mixed 3-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factors Effort Asymmetry (Yes, No) and Inequality by Heuristics (Yes, No) revealed no main effects of Effort Asymmetry, $F(1, 39) = 3.24$, $p = .080$, $\eta_p^2 = .08$, nor of Inequality by Heuristics, $F(1, 39) = 2.90$, $p = .097$, $\eta_p^2 = .07$. Condition, however, had a significant effect on the number of switches, $F(1, 39) = 6.58$, $p = .014$, $\eta^2 = .14$. Overall, pairs made a higher number of switches ($M = 5.4$, $SD = 1.6$) than individuals ($M = 4.3$, $SD = 1.2$). There were no significant interactions of Condition and Effort Asymmetry, $F(1, 39) = 3.07$, $p = .088$, $\eta_p^2 = .07$, nor of Condition and Inequality by Heuristics, $F(1, 39) = 1.53$, $p = .223$, $\eta_p^2 = .04$.

Figure 27

Relative frequency of the Number of Switches Across Conditions



Note. Error bars are 95% confidence intervals.

Strategy Use. When and where participants switched between hands or partners in a task sequence is indicative of which strategy they use. Using perceptual features as a strategy would imply switching when perceptual features of the sequences switched while using turn-taking would imply switching after every item. Minimal coordination would be switching once exactly after four items in the sequence. Task distributions where partners' switches followed the perceptual features of the sequence were assigned to the Perceptual Features (PF) category. Task distributions where partners switched after each item were assigned to the turn-taking category (TT). Task distributions where partners switched in the middle of the sequence were assigned to the minimal coordination category (MC). Any other switching behaviour was not considered a strategy. A mixed 3-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factors Effort Asymmetry (Yes, No) and Inequality by Heuristics (Yes, No) was run for each of the strategies.

Table 11

Percentage of Strategy Use by Condition

Strategy	Individual		Pair	
	M	*SD*	*M*	*SD*
Turn-taking	25.7	29.8	51.2	36.5
Minimal Coordination	12.5	17.5	8.7	20.9
Perceptual Features	39.0	36.6	15.0	30.4

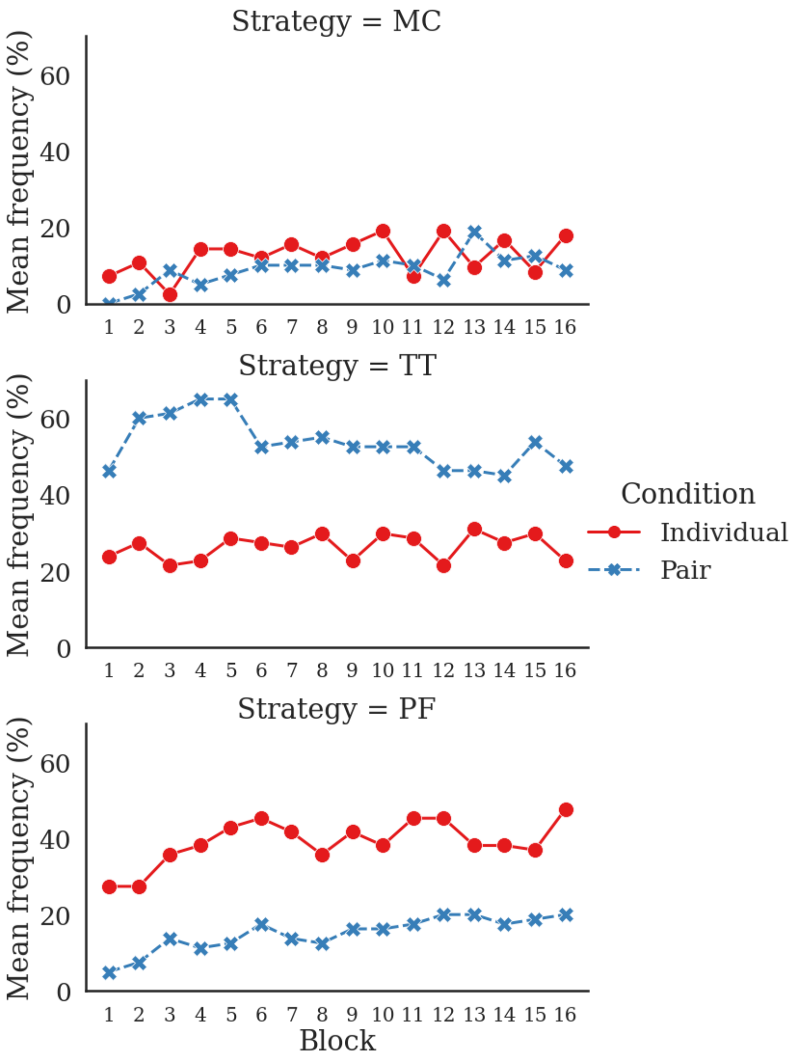
For perceptual features, there was no main effect of Effort Asymmetry, $F(1, 39) = 0.01$, $p = .910$, $\eta_p^2 < .01$, nor of Inequality by Heuristics, $F(1, 39) = 3.37$, $p = .074$, $\eta_p^2 = .08$. There was, however, a significant effect of Condition, $F(1, 39) = 5.45$, $p = .025$, $\eta^2 = .12$. Individuals used perceptual features more frequently (*M* = 39.0%, *SD* = 36.6%) than pairs (*M* = 15.0%, *SD* = 30.4%). There were no significant interactions of Condition and Effort Asymmetry, $F(1, 39) = 0.01$, $p = .910$, $\eta_p^2 < .01$, nor of Condition and Inequality by Heuristics, $F(1, 39) = 2.16$, $p = .149$, $\eta_p^2 = .05$.

For turn-taking, there was a significant effect of Effort Asymmetry, $F(1, 39) = 5.16$, $p = .029$, $\eta_p^2 = .12$. Turn-taking was used more when an effort asymmetry was absent (*M* = 42.8%, *SD* = 36.8%) than when an effort asymmetry was present (*M* = 36.3%, *SD* = 36.0%). There was also a significant effect of Condition on use of TT, $F(1, 39) = 7.03$, $p = .012$, $\eta^2 = .15$. Pairs used more turn-taking (*M* = 51.2%, *SD* = 36.5%) than individuals (*M* = 25.7%, *SD* = 29.8%). The interaction effect between Effort Asymmetry and Condition was not significant, $F(1, 39) = 1.67$, $p = .203$, $\eta_p^2 = .04$. There was no effect of Inequality by Heuristics on frequency of TT, $F(1, 39) = 3.49$, $p = .069$, $\eta_p^2 = .08$, nor an interaction between Condition and Inequality by Heuristics, $F(1, 39) = 3.83$, $p = .057$, $\eta_p^2 = .09$.

For minimal coordination, there was only an effect of Inequality by Heuristics, $F(1, 39) = 5.84$, $p = .020$, $\eta_p^2 = .02$. There was more use of MC when an equal distribution by heuristics was possible (*M* = 13.9%, *SD* = 23.0%) than when it was not possible (*M* = 7.4%, *SD* = 18.0%). There was no effect of Effort Asymmetry, $F(1, 39) = 0.09$, $p = .768$, $\eta_p^2 < .01$, nor of Condition, $F(1, 39) = 0.39$, $p = .537$, $\eta^2 = .01$. There were also no significant interactions between Condition and Inequality by Heuristics, $F(1, 39) = .004$, $p = .948$, $\eta_p^2 < .01$, nor between Condition and Effort Asymmetry, $F(1, 39) = 0.04$, $p = .841$, $\eta_p^2 < .01$.

Figure 28

Mean Frequency (%) of Strategy Use by Block



Note. MC = Minimal Coordination; TT = Turn-taking; PF = Perceptual Features.

Discussion

This experiment was a first attempt at understanding how distributive fairness in terms of effort affects the use of fair procedures in the task distribution process. The results show that while distributive fairness of effort was possibly a concern when planning for a task distribution, using a fair procedure like turn-taking was still generally the task distribution strategy of choice for pairs.

A prediction we made was that if fair procedures are used even if they do not ensure distributive fairness in terms of effort, then turn-taking and minimal coordination heuristics should still be used even if they lead to an unequal distribution of effort. This prediction was supported. While the results show that there was significantly less use of heuristics when an effort asymmetry was present, it was not specific to when either turn-taking or minimal coordination would lead to inequality. Rather, when use of heuristics surely led to an unequal distribution of effort, turn-taking or minimal coordination were still used by pairs to distribute the task. Further evidence in support for this comes from the results on unequal effort distributions, where pairs made close to 50% of unequal effort distributions on average, as expected if heuristics were used for sequences with an effort asymmetry (see Table 10).

Regarding the importance of distributive fairness of effort, we predicted that if distributive fairness guides the use of a fair procedure, then tasks with an effort asymmetry should increase planning difficulty and procedures that lead to an unequal distribution will not be used. This prediction was partially supported. A longer planning time was indeed observed when an effort asymmetry was present in the task and when an equal distribution was not possible via use of heuristics. There was, however, no indication that pairs were coming up with carefully calibrated procedures to ensure distributive fairness. Rather, results from the unequal effort distributions suggest that pairs were still using turn-taking or minimal coordination heuristics despite them leading to an unequal distribution of effort.

Additionally, it seems that individuals acting alone were similarly concerned when an effort asymmetry was present but also failed to come up with a procedure that would ensure an equal distribution of effort between their left and right hands. While individuals took a longer planning time when an effort asymmetry was present in the task, they had a very high frequency of unequal effort distributions. This shows that even with the clear effort asymmetry associated with the colours of each item, individuals were still using the same perceptual features to distribute the task between their two hands.

Another prediction made was that if achieving an equal distribution was generally important, we should expect to see a difference in planning time between pairs and individuals. This prediction was not supported. While both individuals and pairs clearly took a longer planning time when an effort asymmetry was present in the task, there was no significant difference in planning time between individuals and pairs. Additionally, the high number of unequal effort distributions shows that neither individuals nor pairs were able to come up with a procedure that would actually ensure an equal distribution between partners or hands.

An interesting finding from this experiment is the disproportionate use of turn-taking over minimal coordination. In the previous study, minimal coordination was used almost as often as turn-taking. Both strategies were social heuristics that pairs relied greatly on when distributing a task between partners. In this experiment however, pairs clearly preferred turn-taking as a heuristic and hardly used minimal coordination.

A reason for this could be that using minimal coordination to achieve a fair task distribution requires first calculating the total number of steps in the task to determine the minimum number of coordination points for the number of partners involved. When an effort asymmetry is introduced into the task, this would mean calculating the total effort required for the entire task. As some subtasks required more effort than others, the use of minimal coordination runs the risk that one partner completes the first half of the steps while the other partner is unable or unwilling to complete the remaining steps, especially if they require more effort that the first half. In contrast, turn-taking does not require advance calculation and may therefore be the default in situations where effort asymmetries are possible. When partners switch at every turn, the difference between partners in the amount of effort invested at any one point in time is much smaller compared to minimal coordination.

It remains unclear, however, if turn-taking as a fair procedure will still be used if it consistently leads to an unequal distribution. For all 16 sequences used in this experiment, using either minimal coordination or turn-taking would have resulted in an equal distribution of effort for 75% of the time. This is because for sequences with no effort asymmetry, use of heuristics led to an equal distribution of effort even if it was not an equal distribution of the two different coloured type of subtasks (see Figure 18). By simply using turn-taking, pairs would have been able to achieve distributive fairness for 75% of the time. This feature of the experimental design could have led to pairs persisting with turn-taking even if it led to an unequal distribution of effort.

Experiment 2

To further examine how much distributive fairness of effort affects the use of a fair procedure in task distribution, we modified the earlier experiment such that using one fair procedure would more often lead to distributive fairness than using another fair procedure. Accordingly, in Experiment 2, only minimal coordination led to an equal distribution where an effort asymmetry was present in the task. Use of turn-taking in this case would consistently lead to an unequal distribution of effort. This also meant that for the entire experiment, using turn-taking would result in an equal distribution of effort for only 50% of the time, that is, only for tasks that did not imply an effort asymmetry. Using minimal coordination on the other hand, would be fair for 75% of the entire experiment and only fail in the 25% of the tasks where both heuristics did not result in distributive fairness.

If distributive fairness of a task distribution is ignored when fair procedures are available for use, then participants should continue to prefer turn-taking as in Experiment 1. This should result in close to 100% of unequal effort distributions in the condition where an equal effort distribution is not possible.

If distributive fairness influences the selection of the fair procedure used for task distribution, heuristics that have a higher likelihood of producing distributive fairness should more likely be used than heuristics that have a lower likelihood of producing distributive fairness. In the present experiment, this should lead to more frequent use of minimal coordination as compared to turn-taking.

In the previous experiment, we found that achieving an equal distribution of energy expenditure between hands was not very important for individual task distribution. Instead, individuals relied on perceptual features even when it meant that one hand would be used more than the other. Specifically, because the different perceptual features of the items in the task were associated with different effort requirements, use of perceptual features for a task distribution meant that one hand responded to all the difficult high-effort items while the other hand responded to all the easy low-effort items. In this experiment, we used this individual condition as a baseline to compare the performance of pairs. If achieving an equal distribution of effort is important for pairs, planning should be more difficult and take a longer time when turn-taking and minimal coordination both do not lead to an equal distribution of effort. This planning time should also be longer for pairs than for individuals, for whom achieving an equal distribution of effort between hands has little impact on the task distribution process.

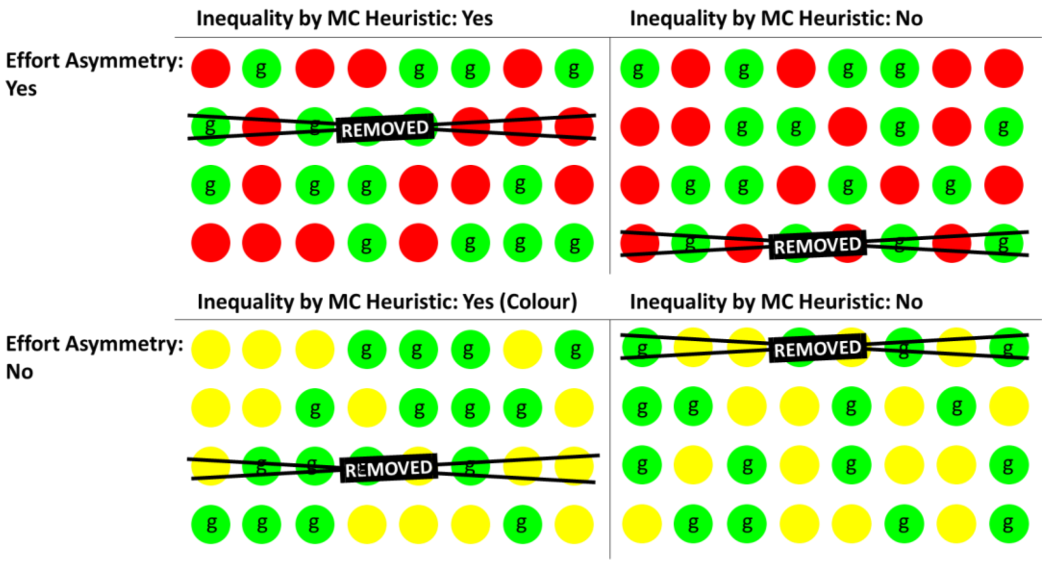
Method

Participants. Sixty-two participants (42 females, age range 18 – 38 years) were recruited through the university's SONA system and a student organization. Twenty-two participants were assigned to the individual condition and 40 participants were assigned to the joint condition, performing the task in 20 pairs. Participants were reimbursed with vouchers worth 1500 Hungarian forints or 1500 Hungarian forints in cash. All participants reported at least conversational skill in English and normal colour vision. The experimental protocol was approved by the United Ethical Review Committee for Research in Psychology, Hungary.

Material and Apparatus. The experimental setup was exactly the same as in Experiment 1. Figure 29 displays the sixteen different stimulus sequences used in Experiment 2. One sequence was found to be added wrongly into the experiment after data collection was done. This sequence was supposed to only allow for an equal distribution by minimal coordination but not by turn-taking. The perceptual features of this particular sequence, however, was arranged such that use of turn-taking was akin to use of perceptual features for task distribution. This meant that it was impossible to determine if perceptual features or turn-taking was used for this sequence. Accordingly, this sequence was removed from data analyses. To ensure a balance of frequencies across the factors, a sequence was randomly picked from the other factor levels and removed (see Figure 29). Data from a total of twelve sequences was analysed in this experiment. As before, all sequences consisted of eight items that required eight separate responses. Green and yellow circles each required one press for a valid response. Red circles required four presses for a valid response. Each sequence consisted of circles in two colours, either green and yellow, or green and red. The items in these sequences were arranged such that when there is an effort asymmetry present, an equal distribution where partners put in an equal amount of effort would be achievable by use of the minimal coordination heuristic, or not at all.

Figure 29

Stimulus Sequences Used in Experiment 2



Note. For purpose of contrast on monochrome displays, items labelled with ‘g’ are green in colour. Items not labelled in the first row (Effort Asymmetry: Yes) are red in colour while items not labelled in the second row (Effort Asymmetry: No) are yellow in colour. No labels were used in the actual experiment.

To compensate for experimenter error, one sequence was removed from each cell of the grid for analyses. For the remaining six sequences in the top row, use of the turn-taking heuristics would surely result in an inequality of effort. MC Heuristic = Minimal Coordination Heuristic.

Table 12

Projected Percentages of Equal Effort Distributions by Use of Different Strategies

Strategy	For Effort Asymmetry: Yes Sequences	For Effort Asymmetry: No Sequences	For the Entire Experiment
Turn-taking	0%	100%	50%
Minimal Coordination	50%	100%	75%
Perceptual Features	0%	100%	50%

Procedure. Procedure and sequence of events for each trial was exactly the same as in Experiment 1. The 16 sequences were also presented in random order in 16 blocks with four repetitions of the same sequence per block. Thus, there were 64 trials total. As before, the first four blocks of the experiment consisted of two sequences with effort asymmetry and two sequences without effort asymmetry, each randomly picked from the total 16 sequences (see Figure 29). Of these four sequences, one sequence with effort asymmetry and one sequence without effort asymmetry led to an unequal distribution via use of the minimal coordination heuristic. The remaining two sequences led to an equal distribution if the minimal coordination heuristic were used. The following four blocks similarly comprised the four different sequence types. This arrangement carried on throughout the experiment until all 16 sequences were presented in 16 blocks. The main experiment took an average of 23.0 minutes for individuals and 24.8 minutes for pairs to complete.

Results

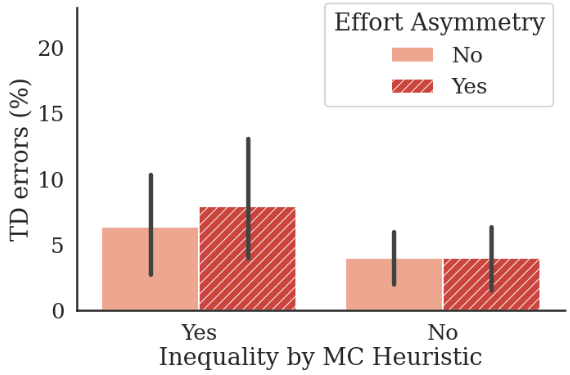
We analysed the same variables as in Experiment 1. Where not indicated otherwise, results were analysed with a 2 x 2 x 2 mixed ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factors Effort Asymmetry (Yes, No) and Inequality by MC Heuristic (Yes, No). One pair and one individual were excluded from the analyses because their total errors deviated more than three standard deviations from the mean in their respective conditions. Data from a total of 21 individuals and 19 pairs were included in the following statistical analyses.

Task Distribution Errors. Pairs made significantly more task distribution errors (*M* = 10.5%, *SD* = 7.6%) than individuals (*M* = 5.7%, *SD* = 5.1%), $F(1, 38) = 5.70$, $p = .022$, $\eta^2 = .13$. While numerically more task distribution errors were made when an effort asymmetry was present (*M* = 8.4%, *SD* = 8.4%) than when there was no effort asymmetry (*M* = 6.7%, *SD* = 6.0%), there was no significant effect of Effort Asymmetry, $F(1, 38) = 1.78$, $p = .191$, η_p^2

= .05. The interaction was also not significant, $F(1, 38) = 0.57$, $p = .457$, $\eta_p^2 = .02$. There was also no effect of Inequality by MC Heuristic, $F(1, 38) = 0.05$, $p = .822$, $\eta_p^2 < .01$, nor of the interaction between Condition and Inequality by MC Heuristic, $F(1, 38) = 2.77$, $p = .105$, $\eta_p^2 = .07$. Unlike in the previous experiment, there was no effect of Effort Asymmetry on task distribution errors for pairs, $t(18) = -1.09$, $p = .289$, $d = -0.25$.

Figure 30

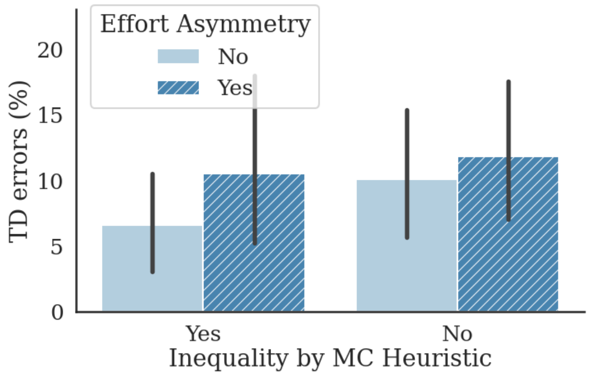
Mean Percentage of Task Distribution Errors Across Factors for Individuals



Note. Error bars are 95% confidence intervals.

Figure 31

Mean Percentage of Task Distribution Errors Across Factors for Pairs

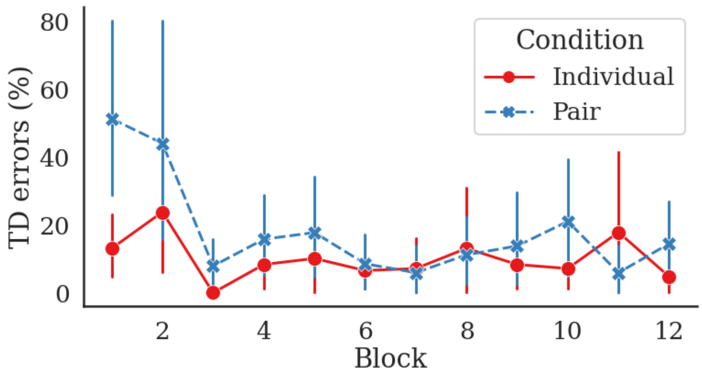


Note. Error bars are 95% confidence intervals.

An additional Greenhouse-Geisser corrected mixed 2-way ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factor Block (1-12) revealed that the proportion of task distribution errors significantly decreased over time, $F(5.77, 219.36) = 3.96$, $p = .001$, $\eta_p^2 = .09$. The interaction was not significant, $F(5.77, 219.36) = 1.63$, $p = .142$, $\eta_p^2 = .04$.

Figure 32

Mean Percentage of Task Distribution Errors Across All 12 Blocks

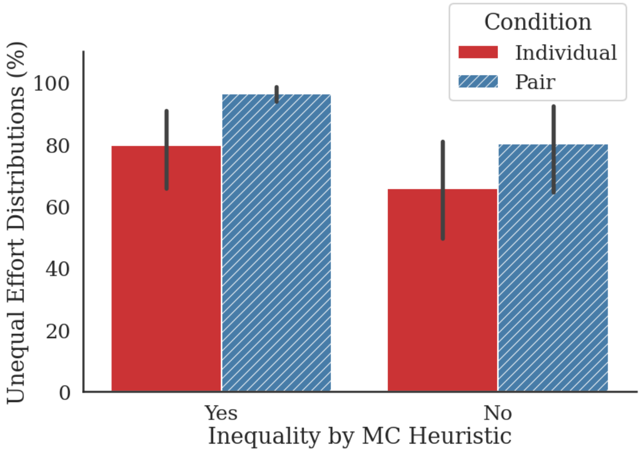


Note. Error bars are 95% confidence intervals.

Unequal Effort Distribution. As with the previous experiment, frequency of unequal effort distributions was derived only from sequences with effort asymmetry. A 2-way ANOVA with Inequality by MC Heuristic (Yes, No) as the within-subject factor and Condition (Individual, Pair) as the between-subject factor revealed a significant effect of Inequality by MC Heuristic, $F(1, 38) = 8.57$, $p = .006$, $\eta_p^2 = .18$. There were significantly more unequal effort distributions when an equal distribution was not possible by the minimal coordination heuristic ($M = 87.7\%$, $SD = 23.5\%$) than when an equal distribution was possible by MC ($M = 72.7\%$, $SD = 35.1\%$). There was also a significant difference in the frequency of unequal effort distributions between individuals and pairs, $F(1, 38) = 4.12$, $p = .049$, $\eta^2 = .10$. Pairs made an average of 88.4% ($SD = 16.0\%$) unequal effort distributions while individuals made an average of 72.8% ($SD = 29.7\%$). There was no significant interaction between Condition and Inequality by MC Heuristic, $F(1, 38) = 0.05$, $p = .821$, $\eta_p^2 < .01$.

Figure 33

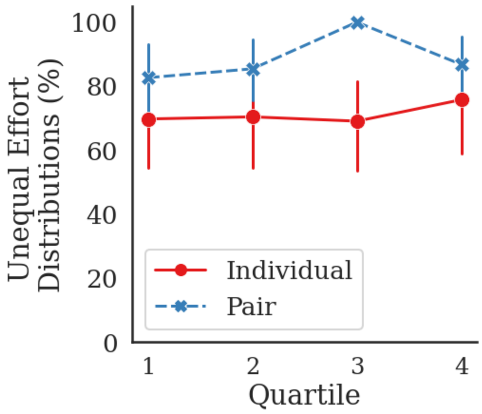
Mean Percentage of Unequal Effort Distributions Across Inequality by MC Heuristic



Note. Error bars are 95% confidence intervals.

Figure 34

Mean Percentage of Unequal Effort Distribution Across All Quartiles



Note. Error bars are 95% confidence intervals.

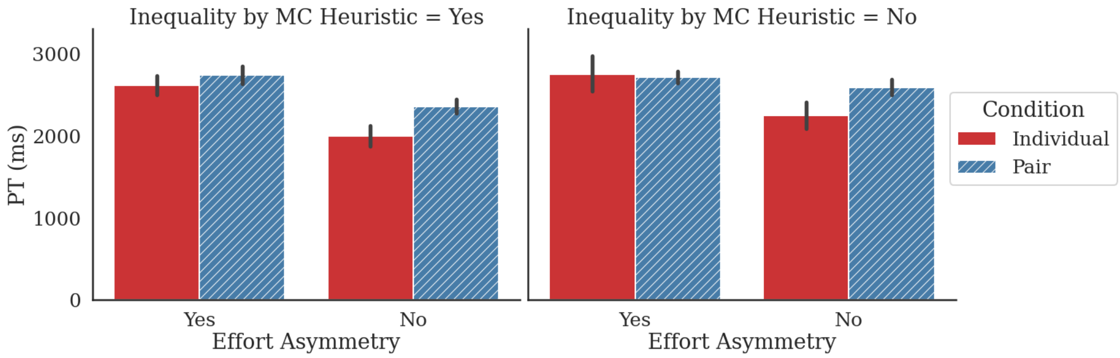
A Huynh-Feldt corrected mixed 2-way ANOVA was run with the between-subject factor Condition (Individual, Pair) and the within-subject factor Quartiles (1-4). The removal of four sequences from the dataset for analysis (see Figure 29) meant that there were missing unequal effort distribution data across quartiles for some participants. For 14 participants (eight individuals), these four removed sequences made up one whole quartile. With only data from three out of the four quartiles, these 14 participants were removed entirely from the analysis. Proportion of unequal effort distributions did not differ overtime, $F(2.51, 60.26)$ =

0.35, p = .753, η_p^2 = .01. There was a significant difference between Condition, $F(1, 24)$ = 5.32, p = .030, η^2 = .18.

Preview Time. There was only a significant main effect of Effort Asymmetry, $F(1, 38)$ = 4.47, p = .041, η_p^2 = .11. Preview times were longer for sequences with Effort Asymmetry (*M* = 2699ms, *SD* = 1493ms) than for sequences with no effort asymmetry (*M* = 2287ms, *SD* = 1052ms). There was no effect of Inequality by MC Heuristic, $F(1, 38)$ = 0.63, p = .432, η_p^2 = .02, nor of Condition, $F(1, 38)$ = 0.29, p = .594, η^2 = .01. There were also no significant interactions of Condition and Effort Asymmetry, $F(1, 38)$ = 0.64, p = .428, η_p^2 = .02, nor of Condition and Inequality by MC Heuristic, $F(1, 38)$ = 0.06, p = .815, η_p^2 < .01.

Figure 35

Mean PT (ms) Across All Factors



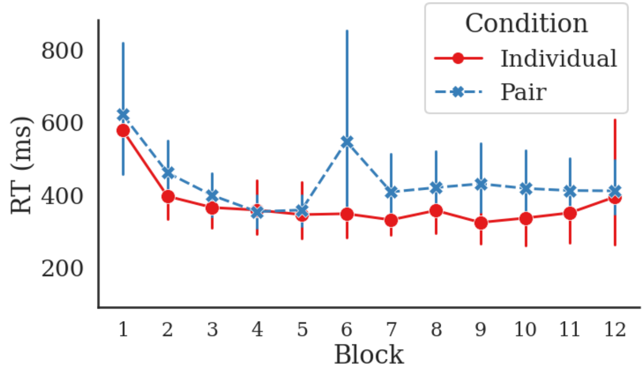
Note. Error bars are 95% confidence intervals.

Both pairs and individuals achieved a faster PT over time. A Greenhouse-Geisser corrected mixed ANOVA showed a significant effect of Block (1-12) on PT, $F(3.09, 117.56)$ = 12.06, p < .001, η_p^2 = .24, but no interaction between Block and Condition, $F(3.09, 117.56)$ = 0.72, p = .547, η_p^2 = .02. Pairs started out at the first block and ended at the last block with a mean PT of 4874ms (*SD* = 2792ms) and 2080ms (*SD* = 1175ms), respectively. Individuals started out at the first block and ended at the last block with a mean PT of 5932ms (*SD* = 5795ms) and 1765ms (*SD* = 1827ms), respectively.

Reaction Time. There were no effects of Effort Asymmetry, $F(1, 38) = 1.35$, $p = .252$, $\eta_p^2 = .03$, nor of Inequality by MC Heuristic, $F(1, 38) = 2.28$, $p = .139$, $\eta_p^2 = .06$. There was also no significant difference between individuals and pairs, $F(1, 38) = 1.72$, $p = .197$, $\eta_p^2 = .04$. Using a Greenhouse-Geisser corrected mixed ANOVA with the between-subject factor Condition (Individual, Pair) and the within-subject factor Block (1-12), we find a significant Block effect on RT, $F(3.80, 144.35) = 4.12$, $p = .004$, $\eta_p^2 = .10$. Pairs started out at the first block and ended at the last block with a mean RT of 621ms (*SD* = 429ms) and 411ms (*SD* = 165ms), respectively. Individuals started out at the first block and ended at the last block with a mean RT of 578ms (*SD* = 310ms) and 394ms (*SD* = 454ms), respectively. There was no significant interaction effect of Block and Condition, $F(3.80, 144.35) = 0.65$, $p = .618$, $\eta_p^2 = .02$.

Figure 36

Mean RT (ms) Across All 12 Blocks



Note. Error bars are 95% confidence intervals.

Switches per Sequence. There was a main effect of Inequality by MC Heuristic, $F(1, 38) = 4.88$, $p = .033$, $\eta_p^2 = .11$, and of Effort Asymmetry, $F(1, 38) = 5.43$, $p = .025$, $\eta_p^2 = .13$. More switches were made when an equal distribution by the minimal coordination heuristic was possible (*M* = 4.5, *SD* = 1.7) than when an equal distribution by MC was not possible (*M* = 4.2, *SD* = 1.5). More switches were also made when there was an effort asymmetry (*M* = 4.5, *SD* = 1.6) than when there was no effort asymmetry (*M* = 4.1, *SD* = 1.5). There was no effect of Condition, $F(1, 38) = 3.17$, $p = .083$, $\eta^2 = .08$. There was also no significant interaction of Condition and Inequality by MC Heuristic, $F(1, 38) = 0.13$, $p = .721$, $\eta_p^2 < .01$, nor of Condition and Effort Asymmetry, $F(1, 38) = 0.59$, $p = .447$, $\eta_p^2 = .02$. There was, however, a significant interaction of Inequality by MC Heuristic and Effort Asymmetry, $F(1, 38) = 9.33$, $p = .004$, $\eta_p^2 = .20$. The three-way interaction was not significant, $F(1, 38) = 3.98$, $p = .053$, $\eta_p^2 = .10$.

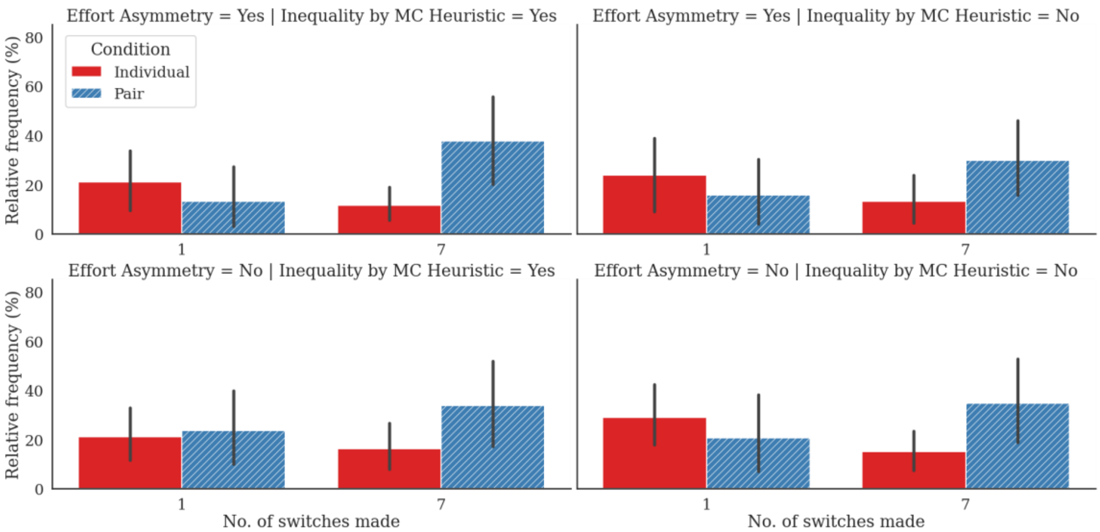
Table 13

Mean Number of Switches by Inequality by MC Heuristic and Effort Asymmetry

Effort Asymmetry	Inequality by MC Heuristic: Yes		No	
	M	*SD*	*M*	*SD*
Yes	4.4	1.6	4.6	1.8
No	3.8	1.6	4.4	1.6

Figure 37

Relative frequency of the Number of Switches Across All Factors



Note. Error bars are 95% confidence intervals.

Strategy Use. For perceptual features (PF), there was no main effect of Effort Asymmetry, $F(1, 38) = 0.02$, $p = .903$, $\eta_p^2 < .01$, nor of Inequality by MC Heuristic, $F(1, 38) = 0.05$, $p = .834$, $\eta_p^2 < .01$. There was also no effect of Condition on frequency of PF, $F(1, 38) = 0.55$, $p = .462$, $\eta^2 = .01$.

For turn-taking (TT), there was only a significant effect of Condition, $F(1, 38) = 5.52$, $p = .024$, $\eta^2 = .13$. Pairs used more turn-taking (*M* = 33.9%, *SD* = 34.8%) than individuals (*M* = 13.3%, *SD* = 17.5%). There was no effect of Effort Asymmetry on use of TT, $F(1, 38) = 0.28$, $p = .603$, $\eta_p^2 = .01$, and no effect of Inequality by MC Heuristic on frequency of TT, $F(1, 38) = 0.64$, $p = .427$, $\eta_p^2 = .02$. There was also no significant interaction between Condition and Effort Asymmetry, $F(1, 38) = 0.16$, $p = .689$, $\eta_p^2 < .01$, nor between Condition and Inequality by MC Heuristic, $F(1, 38) = 0.81$, $p = .374$, $\eta_p^2 = .02$.

For minimal coordination (MC), there was only an effect of Effort Asymmetry, $F(1, 38) = 5.29$, $p = .027$, $\eta_p^2 = .12$. There was more use of MC when no effort asymmetry was present in the task (*M* = 22.9%, *SD* = 29.2%) than when it was (*M* = 18.4%, *SD* = 28.3%). There was no effect of Inequality by MC Heuristic, $F(1, 38) = 0.79$, $p = .379$, $\eta_p^2 = .02$, nor of Condition, $F(1, 38) = 0.38$, $p = .539$, $\eta^2 = .01$. There was also no significant interaction between Condition and Effort Asymmetry, $F(1, 38) = 1.99$, $p = .166$, $\eta_p^2 = .05$, nor between Condition and Inequality by MC Heuristic, $F(1, 38) = 0.79$, $p = .379$, $\eta_p^2 = .02$.

Table 14

Percentage of Strategy Use by Condition

Strategy	Individual		Pair	
	M	*SD*	*M*	*SD*
Turn-taking	13.3	17.5	33.9	34.8
Minimal Coordination	22.9	27.7	16.2	28.6
Perceptual Features	36.3	33.8	30.7	34.2

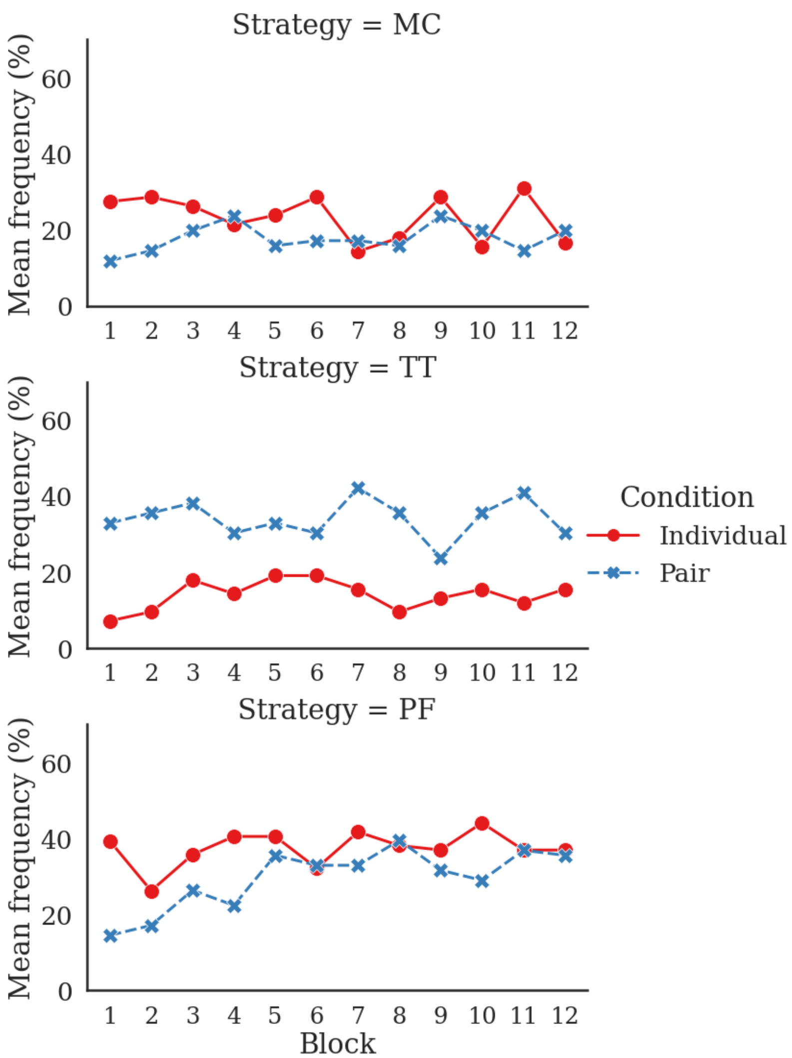
Table 15

Percentage of Strategy Use by Condition for the Sequence Added Wrongly in this Experiment

Strategy	Individual		Pair	
	M	*SD*	*M*	*SD*
Turn-taking / Perceptual Features	51.2	45.1	69.7	37.8
Minimal Coordination	25.0	36.2	14.5	32.6

Figure 38

Mean Frequency (%) of Strategy Use by Block



Note. MC = Minimal Coordination; TT = Turn-taking; PF = Perceptual Features.

Discussion

The results of Experiment 2 corroborate and extend the findings of the first experiment. They add evidence that, indeed, distributive fairness of effort is of little import when a fair procedure can be used. Specifically, a fair procedure that was more likely to generate distributive fairness (i.e., minimal coordination) was not used more often than a procedure that was less likely to generate distributive fairness (i.e., turn-taking).

We predicted that if distributive fairness can be ignored when a fair procedure is available for use, then turn-taking should still be used even if it never leads to an equal distribution of effort when an effort asymmetry is present in the task. This prediction was supported. Albeit at a less frequent rate as compared to Experiment 1, pairs still preferred turn-taking over other strategies, and used it significantly more than individuals. This finding further adds to our evidence so far that pairs will ignore the lack of distributive fairness in terms of effort and be content with simply ensuring procedural fairness for their task distributions. Naturally, because pairs were still using turn-taking even when it led to an unequal distribution or were unable to discover an alternative procedure that would lead to distributive fairness, frequency of unequal effort distributions were much higher than in Experiment 1.

Nevertheless, pairs were using turn-taking less frequently in this experiment as compared to pairs in Experiment 1. This suggests that pairs in this experiment were at least somewhat sensitive to the lack of distributive fairness that would result from turn-taking and thus used it less. This could be due to the presence of the sequence added wrongly in the experiment. For that sequence, the use of turn-taking very clearly indicates that one partner has to respond to all the difficult high-effort red items while the other partner will respond to all the easy low-effort green items. This sequence might have discouraged participants from using a strategy that clearly would not result in an equal distribution of effort and to opt instead for a strategy that would lead to distributive fairness. Inspection of how frequently the different strategies were used for this particular sequence suggest, however, that this was not the case. While it was impossible to distinguish use of perceptual features from turn-taking for this sequence, there was no clear indication that minimal coordination, which would ensure an equal distribution of effort, was used over perceptual features or turn-taking to ensure distributive fairness.

Indeed, as in Experiment 1, pairs used minimal coordination the least, even though minimal coordination in this experiment would have ensured distributive fairness more often than turn-taking. This means that pairs did not attempt to evaluate which of the two fair procedures would actually ensure greater distributive fairness in terms of effort. This interpretation is also supported by the finding that there was no difference in planning time between tasks where an equal distribution was possible via use of minimal coordination heuristic or not. If pairs were at least evaluating if a fair procedure would lead to distributive fairness, sequences for which use of minimal coordination would lead to an equal distribution of effort should be easy to plan for. Planning time for these sequences should therefore be shorter as compared to sequences for which both minimal coordination and turn-taking do not lead to distributive fairness. It is clear from the results, however, that this was not the case.

A surprising finding from this experiment is that rather than using minimal coordination, pairs were more often opting to use perceptual features of the task for their task distributions. In fact, the rate of using perceptual features for task distribution was just slightly less than that of turn-taking for pairs. Considering that using perceptual features led to an unequal distribution of effort for 50% of the overall trials (see Table 12), it is curious why pairs chose such a procedure over minimal coordination, a strategy which would ensure an equal distribution of effort for 75% of all trials in the entire experiment. One possible reason could be that the sequence that was added wrongly to the experiment encouraged the use of turn-taking as much as the use of perceptual features for task distribution. This could have led participants to see use of perceptual features as an immediate next best option throughout the experiment.

Another possible reason was that pairs were using perceptual features and trying unsuccessfully to take turns across trials instead, following the recipe that 'I will take the difficult colour in this trial and you will take the difficult colour in the next trial'. This would ensure an overall equal distribution of effort for a task that has an effort asymmetry present. This potential use of perceptual features and turn-taking across trials could also help explain why turn-taking was generally used less frequently in this experiment as compared to Experiment 1. In the first experiment, turn-taking would have led pairs to achieve an equal distribution of effort between partners for 75% of the time. In this experiment, turn-taking would have led pairs to achieve an equal distribution of effort for only 50% of the time. If perceptual features were successfully used with turn-taking across trials, however, this would have led pairs to achieve distributive fairness for 100% of the time. Unfortunately, no statistical analysis could be run to test this assumption as only 8 individuals and 6 pairs had task distributions where they used perceptual features consistently throughout all four trials of a block.

General Discussion

The goal of this study was to examine if and how distributive fairness of effort influences the use of fair procedures in task distribution planning. To do this, we designed two experiments where applying a fair procedure did not lead to distributive fairness of effort. We found that where distributive fairness was difficult to achieve, pairs relied solely on procedural fairness in their task distributions. Additionally, we found that pairs did not seem to pay attention to which fair procedure actually ensured distributive fairness but instead opted for the first fair procedure that came to mind. In this case, turn-taking was the first fair procedure that came to mind and this was likely because turn-taking is highly ubiquitous in everyday life and was easier to execute than minimal coordination. This was the case even when the minimal coordination heuristic provided a more effective way to achieve distributive fairness than turn-taking.

Regarding the role of distributive fairness in planning, we find that while planning times in both experiments increased when an effort asymmetry was present in the task, the high rate of unequal effort distributions indicates that the additional planning had little impact on how task distributions are performed. Additionally, if distributive fairness was important, the presence of an effort asymmetry in the task should result in pairs taking a longer planning time than individuals. This was not found in both experiments.

While distributive fairness had little impact on the use of a fair procedure in this study, it would be hasty to conclude that distributive fairness plays no role, at all, in all kinds of task distributions. If procedural fairness was all that was needed to achieve a fair task distribution, there should be no difference between planning times for task sequences with effort asymmetry and planning times for task sequences with no effort asymmetry. This was evidently not the case. The significantly longer planning time for sequences with effort asymmetry indicates that participants were at least aware of an asymmetry in the task and the difficulty of achieving distributive fairness for such a task. Additionally, the lack of response time differences across conditions indicates that once participants had decided on a plan, they were going through with their plan without hesitation.

Another prediction made was that if distributive fairness is not a precondition for the use of a fair procedure, both turn-taking and minimal coordination heuristics should be used even if they lead to an unequal distribution of effort. This was not supported. If procedural fairness was indeed all that was required to achieve a fair task distribution, there should also be no difference in how frequently turn-taking or minimal coordination heuristics are used. In other words, since the fairness of the resulting distribution would be of no concern, at all, it does not matter which heuristics are used. In both experiments, however, we observed a clear preference for turn-taking, even when it consistently led to an unequal distribution where one partner put in more effort than the other. This disproportionate use of turn-taking over minimal coordination indicates that when distributive fairness is difficult to achieve, the ease of applying a procedure is another factor that could influence task distribution. In the current experiments, we found that turn-taking and use of perceptual features (see Experiment 2) was preferred over minimal coordination, possibly because minimal coordination was harder to apply. Minimal coordination would require that participants consider the whole task sequence whereas turn-taking and use of perceptual features can be applied without keeping the whole task sequence in mind.

Indeed, ease of execution may have been an important factor when planning for a task distribution in this study. To ensure distributive fairness, one would need to compute the overall effort of the task sequence to then derive what a fair distribution looks like. Turn-taking may have stood out clearly as an easy and fair procedure for a task distribution and does not require a lot of advance computation during the planning phase. Importantly, this would imply that participants relied not only on procedural fairness for their task distributions but also on whatever procedure was easiest to implement.

Considering that partners were not allowed to talk to each other in both experiments, the use of a procedure that minimises advance planning would help considerably in coming up with a fair task distribution. This would also imply that it was not that distributive fairness was unnecessary when planning for a task distribution but that distributive fairness appeared too difficult to achieve in these task distributions, especially when a fair and easy to implement procedure (i.e., turn-taking) was available. It remains to be seen however, if the use of perceptual features for task distribution in Experiment 2 was meant to be executed with turn-taking across the repeated trials of the same task sequence. It would definitely be an effective way of maintaining an overall fair distribution of effort between partners and possibly, still constitute a less demanding strategy than the use of minimal coordination.

Another contributing reason for the more frequent use of turn-taking over minimal coordination might be that there were no explicit instructions given to participants to ensure an equal distribution of effort between partners (or hands). Participant were only asked to ensure that each partner (or hand) respond to half of the items in a sequence. This meant that nothing kept pairs from focusing on achieving a task distribution where each partner responds to the same number of items, thereby finishing the experiment without investing too much cognitive effort. The actual consequence of one partner contributing more in terms of effort to a task distribution may matter less than the cognitive effort required to achieve distributive fairness, especially when there was an easy way to at least ensure some level of fairness with the use of a fair procedure.

There is, however, also the possibility that these experiments were underpowered and that a larger sample size could reveal a clearer story of how distributive fairness of effort influences the use of fair procedures in task distribution planning. In the first experiment, the effect of Inequality by Heuristics and its interaction with Condition on the frequency of turn-taking were both close to significance. The interaction between Inequality by Heuristics and Condition on unequal effort distributions was also similarly close to significance, suggesting that pairs may not be ignoring distributive fairness entirely. A replication of the first experiment with a bigger sample and of the second experiment with a full set of task sequences would be necessary to provide more conclusive interpretations of the role that distributive fairness plays in the task distribution process.

Taken together, the results from this study indicate that while pairs relied on procedural fairness when distributive fairness of effort was difficult to achieve, the ease of implementing a certain task distribution was an important factor influencing how a fair task distribution was eventually performed. When distributive fairness was too difficult to achieve, pairs relied on procedural fairness and chose the easier procedure, which was turn-taking.

A next step to consider now would be to examine if ease of execution would feature as strongly when it comes to a distribution of resources. In this study, partners were distributing a task that would be considered a chore and which was not incentivised according to the amount of effort invested. While distributive fairness had little bearing on which procedure was used in this study, it is possible that distributive fairness would have a stronger effect on the choice of procedure when resources are involved.

In a society where much depends on the cooperation of multiple individuals, the findings of this and future studies on procedural fairness and distributive fairness in task distribution can certainly be helpful. Besides aiding in examining the cognitive processes that are involved when planning for a fair task distribution, these studies could also enhance our understanding of why some tasks result in a fair distribution between partners and some not. From this current study, we found that it was the ease of implementing a task distribution that led to the use of a specific fair procedure and its resulting unfair distribution of effort.

That the ease of achieving either procedural or distributive fairness can determine the fairness of a task distribution has several social implications, chief of which is the entrenchment of distributive inequality for the convenience of a fair procedure. A day-to-day example would be the practice of Going Dutch when dining with a group of friends. A fair and easy procedure would be to divide the total bill by the total number of people at the table.

This would, however, not ensure distributive fairness since not everyone ate the same amount of food nor would everyone have ordered similarly priced items. To ensure distributive fairness, one would have to pick out which items were eaten or shared by whom, and to calculate the additional tax and service charge on top of that. While this would not be too difficult for a group of two friends, ensuring that everyone paid their fair portion of the bill for a group of five friends or more might involve too much effort to even start.

Chapter 3: Imagining a Fair Task Distribution

In almost every setting that requires a joint effort, there is a dream team we imagine perfect for the task. As with most things in life however, the best laid plans of mice and men often go awry. People are generally overly optimistic when planning, even in the face of contrary precedents (Buehler et al., 2010; Kahneman & Tversky, 1982) or even when such wishful thinking is penalized (Babad & Katz, 1991; Massey, Simmons, & Armor, 2011). Between partners, planning to work together often involves coordinating actions, and making inferences about others' intentions and goals (Bratman, 1993). This ability to make inferences about others is termed mentalizing (Apperly & Butterfill, 2009; U. Frith & Frith, 2003; Lombardo et al., 2010) and while considered important to understanding the perspective of others and in predicting their actions (Amodio & Frith, 2006; C. D. Frith & Frith, 2006a; Spiers & Maguire, 2006), has its limitations (Keysar et al., 2003). People may be able to understand how exactly perspectives are different but not necessarily act on them accordingly. Additionally, while there is often an intuitive preference for people to be fair and cooperative (Rand, 2016; Rand et al., 2014), achieving a fair task distribution is not always straightforward. A fair procedure can be preferred even if it leads to an unfair distribution of rewards (Grocke, Rossano, & Tomasello, 2015) and a fair outcome need not always be the result of what is considered a fair procedure (Konovsky, 2000).

Indeed, planning is not easy, let alone planning for projects that involve multiple parties (Kahneman & Tversky, 1982). The number of conflicts that could arise are plenty and as a result, plans are constantly revised on the go (Schilbach, 2014). Oftentimes, turn-taking is used to navigate the conflicts that occur in environments with a common pool of resources (Lau & Mui, 2012; Ostrom, 1990) or in situations where just one individual's effort is needed for the benefit of the group (Leo, 2017). Sometimes, appointing a leader helps in ensuring a smooth joint action (Sacheli, Tidoni, Pavone, Aglioti, & Candidi, 2013; Tomasello, 2009b).

Sometimes, familiarity with partners' expertise is enough to ensure success (Noy et al., 2011; Wegner et al., 1991). Sometimes too, salient features in the environment or a task can serve as focal points of coordination for partners, especially when communication is difficult or absent (Mehta et al., 1994; Schelling, 1980). Naturally, with the diversity of social settings in this world, there are many ways that can help facilitate a successful coordination between partners. Needing to plan for a joint task then, what would be the strategy one imagines best for the situation? In planning who does what and when, what determines the best strategy?

Assessing the Contents of a Plan

One way to access the planning stage of a joint action would be to use brain measures to infer what processes might be going on before the execution of the joint action. In this regard, research using electroencephalography (EEG) has found that planning for a joint action likely involves parcelling out attention to where the actions of one's own and one's partner are expected (Kourtis, Knoblich, Woźniak, & Sebanz, 2014). Individuals also likely represent the expected actions of their partners in order to facilitate coordination, resulting in EEG signatures that were different from when the same individuals were performing their same actions alone (Kourtis, Sebanz, & Knoblich, 2013).

To specifically access the contents of a plan however, one way would be to infer retrospectively from the performance. As is common however, especially when a task involves a collaborative effort from multiple people, things do not always go according to plan (Pinto, 2013). Not only are people often overly confident and overly optimistic when they plan (Buehler et al., 2010; Kahneman & Tversky, 1982), they are also capable of affecting and revising a plan while a joint action is being performed (Schilbach, 2014). Additionally, observing actions of a task partner may trigger automatic mimicry (Chartrand & Bargh, 1999) and this effect can be greater for groups observing group actions (Tsai, Sebanz, & Knoblich, 2011). For joint action situations where partners contribute different actions, as in the way musicians often do in duets, partners may engage in a monitoring process of both their partner's and their own actions (Loehr et al., 2013). If something unexpected happens, partners are also capable of adapting to each other at the timescale of millisecond (Konvalinka, Vuust, Roepstorff, & Frith, 2010). Thus, performance does not necessarily exclusively correspond to an initial plan joint action partners thought of but may also reflect revisions of a plan during joint action execution.

A second way to access the mental contents of a plan would be to use thought-listing, a method where participants simply list all the thoughts that they had while planning for the task (Buehler et al., 1994; Peetz et al., 2010). There are limitations to using thought-listing, however. For example, when thinking aloud during the planning stage, deadlines were hardly ever mentioned even though they were a significant factor on how long people predict they will take to complete a task (Buehler et al., 1994). Rather, the authors found that people were focusing very much on the future and mentioning little of past relevant experiences. Additionally, there is the risk of introducing measurement reactivity with the use of thought-listing, particularly during tasks with high cognitive demand (Cacioppo et al., 1997). In this case, the thoughts reported are likely to be more in reaction to the listing procedure than a part of the planning process.

Implementing the Best Laid Plan

A new method proposed here to examine how people plan for a joint task is to have them perform a task individually the way they would in a social context with a partner. This means planning for a joint task to be performed by two partners but implementing it such that a person's left and right hands can be used to represent two imaginary partners performing a joint task. This is on the assumption that as one gains more control over how a joint action should be carried out, the chances of potential obstacles actually happening in this imaginary joint mode would be greatly minimized. The behavioural measures obtained then would not only reflect the best laid plan that people had for a joint task, but also reveal the common planning approach people prefer when needing to distribute a task between themselves and a partner.

In our previous studies, we found that pairs relied very much on using a temporal order of actions in their task distribution. Across five experiments in two studies, pairs were using heuristics like turn-taking and minimal coordination in their task distributions (Chapter 1: The Role of Mentalizing, Social Heuristics, and Perceptual Task Features), even when use of these heuristics would lead to an unfair distribution of effort between partners (Chapter 2: Procedural and Distributive Fairness in a Joint Task Distribution). In contrast, individuals planning for a task distribution between their two hands relied on a featural order of actions. Specifically, individuals made use of perceptual features in the task to guide their task distributions.

Interestingly, in the second study (Chapter 2), while pairs were still using turn-taking even when it led to an unfair distribution of effort between partners, there were signs that pairs may have attempted to use a different task distribution strategy to achieve distributive fairness of effort. In Experiment 2 of that study, pairs started to switch from using a temporal order of actions to using a featural order where perceptual features in the task sequence determined who responded to what and when. However, as perceptual features in those task sequences were associated with different effort requirement, distributing a task by use of this featural order also resulted in an unequal distribution of effort.

The aim of the present study was to examine if contrasting the imaginary joint performance with individual performance would yield the same difference as contrasting real joint performance with individual performance. If the performance and preference for heuristics use found in the real joint performance are similarly observed in the imaginary joint performance, this would imply that people can enter an imaginary joint action planning mode that leads to the same pattern of task distributions and heuristic use as in the context of joint performance.

The Present Study

To test this new method of examining the planning process of a task distribution, we used two experiments from the previous studies. The first experiment is from Study 1 Experiment 1 (Chapter 1: The Role of Mentalizing, Social Heuristics, and Perceptual Task Features) and it allowed us to examine what the cognitive mechanisms are when individuals plan for a joint task distribution for two partners. In this earlier experiment, a task sequence of eight items was first presented as a preview. At this point of preview, individuals were asked to plan how they would later respond to each item such that each partner responds to the task equally often. A key difference between the current study and the previous study is that instead of individuals performing the planned task distribution as one out of two partners, individuals performed both parts of the planned task distribution in an imaginary joint condition, with one hand acting for each partner. Specifically, individuals were asked to imagine that their left and right hands were their friends and that both friends needed to achieve a fair task distribution where each friend responded equally often.

The second experiment of this present study is comparable to Study 2 Experiment 2 (Chapter 2: Procedural and Distributive Fairness in a Joint Task Distribution). This experiment allowed us to examine how distributive fairness of effort guides the use of a fair procedure in task distribution. Instead of performing the task distribution as one out of two partners as before, individuals in this present study were similarly asked to perform the task of both partners, with each hand acting for one imagined partner. The imaginary joint condition where individuals planned for a fair task distribution and performed both roles in an imaginary joint mode was contrasted with an individual condition where individuals planned and performed a fair task distribution for their two hands. Note that while individuals in both conditions were technically performing the same task distribution with their two hands, individuals in the critical imaginary joint condition may approach the task distribution in a manner that is similar to the task distribution patterns observed in real joint action.

General Predictions

If planning for a fair task distribution in the imaginary joint mode corresponds to the planning people do for an actual joint task distribution, we expect to see more use of turn-taking and minimal coordination heuristics in the imaginary joint condition than in the individual condition.

Experiment 1

Experiment 1 provided a first test of the new method and a first attempt to examine if the cognitive mechanisms involved when planning a task distribution in the imaginary joint mode are similar to those involved in planning for an actual joint task distribution. Like before, we manipulated sequences such that the perceptual features of eight items denoting eight subtasks either alternated by one, alternated by two, or alternated by four. If planning a task distribution in the imaginary joint mode is no different to planning an actual joint task distribution, individuals distributing a task in the imaginary joint condition should use more of turn-taking and minimal coordination heuristics than individuals distributing a task in the individual condition. Alternatively, if planning a task distribution for two imaginary partners is no different to planning a task distribution for one's own two hands, individuals distributing a task in the imaginary joint condition should make their task distributions according to how the perceptual features in the task alternate, the same way individuals distributing a task for two hands in the individual condition would.

Another finding from the previous experiment with actual pairs (Study 1 Experiment 1) was that pairs seem to mentalize more than individuals. This was indicated by a longer preview time when planning for joint task distributions. With this current experiment, however, it will be an open question as to how much planning in an imaginary joint mode is about predicting the potential coordination problems imaginary partners face. If planning for a task distribution in the imaginary joint mode involves thinking about potential coordination problems the same way planning for an actual joint task distribution does, we would expect the same difference in planning time between joint and individual task distribution for imaginary joint and individual task distribution.

Previously, to address the role of mentalizing in task distribution planning, we manipulated whether the mappings between stimuli and responses were ambiguous or unique. Unique task sequences used unique mappings where both stimulus features (colour and form) of an item required the same response in a two-choice task. Ambiguous task sequences used ambiguous mappings where each stimulus feature of an item required a response different from the other. Previously, ambiguity in the task would create additional coordination problems which led to pairs taking a longer planning time than when unique mappings were used. If planning for a task distribution in the imaginary joint mode involves thinking about the potential coordination problems the same way planning for an actual joint task distribution does, we would similarly expect a longer planning time for ambiguous tasks than for unique tasks.

Method

Participants. Sixty-two participants (31 females, age range 19 – 54 years) were recruited through the university's SONA system and a student organization. Thirty-one participants were assigned to the individual condition and 31 participants were assigned to the imaginary joint condition. Participants were reimbursed with vouchers worth 1500

Hungarian forints or 1500 Hungarian forints in cash. All participants reported at least conversational skill in English and normal colour vision. The experimental protocol was approved by the United Ethical Review Committee for Research in Psychology, Hungary.

Material and Apparatus. In the individual condition, a 22-inch monitor was set on the table about 50cm away from where the participant was seated. On the table between the monitor and the participant was a controller box with four white circular buttons. Only the two outer buttons were used in the experiment. For the imaginary joint condition, the keys ‘a’, ‘s’, ‘k’, and ‘l’ of the standard QWERTY keyboard were used instead, with ‘a’ and ‘s’ being the left and right keys of one partner and ‘k’ and ‘l’ being the set of left and right keys for the other partner (see Figure 39). The experiment was programmed using E-prime 2.0 on the Windows 7.0 Professional operating system on a Dell Precision T5610 computer.

This experiment used the same twelve stimulus sequences used in Study 1 Experiment 1 (Figure 1). As before, all sequences consisted of eight items that required eight separate responses. Each item consisted of a combination from two forms (triangle, circle) and two colours (yellow, green). Each individual sequence used only two out of the four elements, yellow triangles and green circles, or yellow circles and green triangles. The items in these sequences either alternated by one (i.e., A-B-A-B-A-B-A-B), two (i.e., A-A-B-B-A-A-B-B), or four (i.e., A-A-A-A-B-B-B-B), so that items switched either 7 times (Alternate by 1), 3 times (Alternate by 2), or once (Alternate by 1).

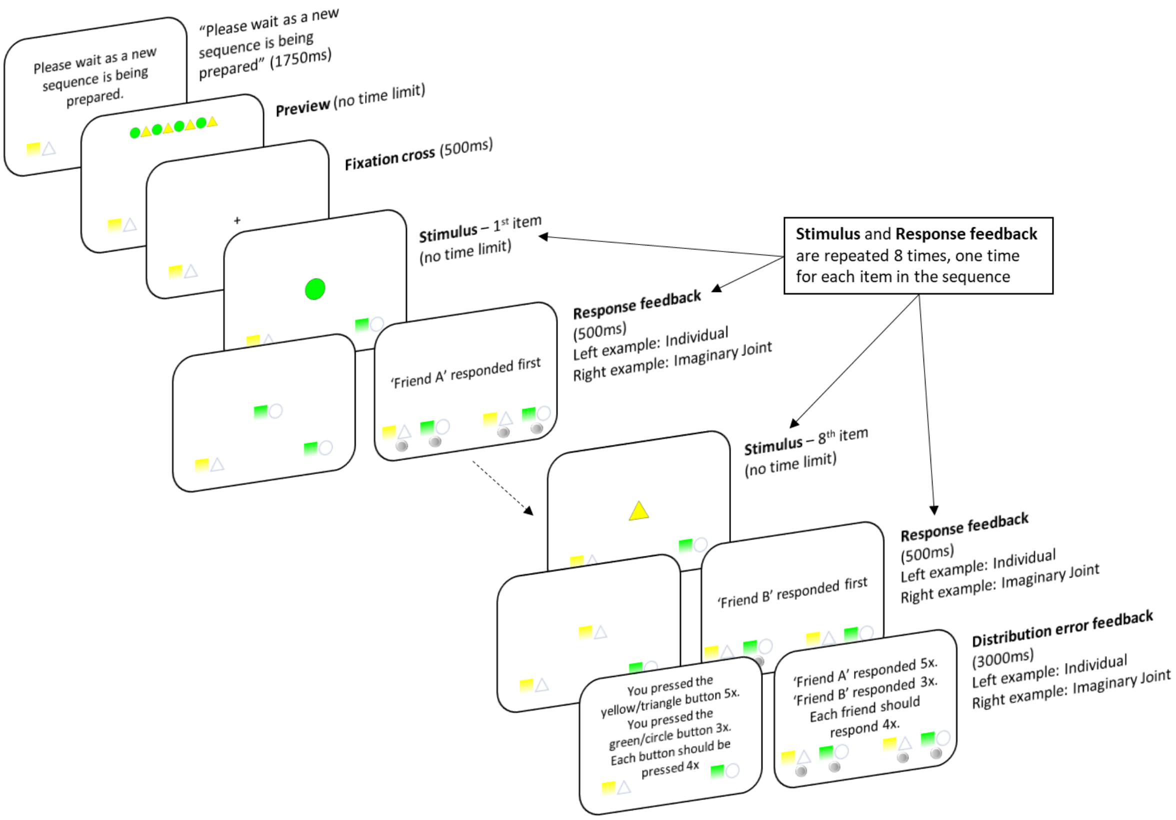
Procedure. After participants signed informed consent, they were introduced to the experimental setup. Participants in the imaginary joint condition were told to input the names of their two friends that they will be playing as into the game. Participants were informed that their task was to respond to sequences of eight items and that a preview of the eight items would be first presented in each trial. The instructions encouraged them to plan in advance how to respond to the whole sequence of items so that both friends respond equally often (in the imaginary joint condition) or so that each of the two buttons is pressed equally often (in the individual condition).

The task for each item in a sequence was to respond to yellow items OR triangles with the left key and to green items OR circles with the right key. Importantly, this implied that participants could choose which stimulus dimension to respond to. For 6 out of the 12 stimulus sequences this created a task ambiguity because the different stimulus dimensions colour and form required different responses (see Figure 1). For instance, a yellow circle required pressing the left button when responding to colour and pressing the right button when responding to form. Note that this task ambiguity implied that pressing any of the two available buttons yielded a correct response. For the remaining six stimulus sequences there was no task ambiguity because form and colour required the same response for each item. For instance, a yellow triangle required a left response, regardless of whether a participant responded to form or colour. Participants were instructed to respond to each item in the sequence as quickly as possible after the planning period.

The experiment started with a short familiarization phase where the procedure and the main elements of the task were introduced to the participants. In each trial of the experiment (see Figure 39) participants in the imaginary joint condition were first shown a preview of the eight-item sequence. There was no time limit to the preview. Participants pressed a button for each friend when ready to proceed. The trial then continued, after which, a fixation cross appeared in the centre of the screen for 500ms. After the fixation cross, each stimulus item in the sequence appeared individually, in the centre of the screen, and remained there until a response was made.

Figure 39

Sequence of Events For Each Trial in Experiment 1



Note. The mappings of stimulus features to response keys were displayed on the bottom of the screen throughout the entire experiment. For participants in the individual condition, this was two response keys total. For participants in the imaginary joint condition, it was two response keys per each friend, resulting in four response keys total.

The first button press was counted as the response. Depending on which hand pressed the button first, a feedback reflecting the friend associated with that hand was shown for 500ms. For example, with left hand being Julia and making the first response, 'Julia responded first'. After all eight items in the sequence had been shown and eight responses had been collected, a feedback appeared for 3000ms if the task distribution between friends was not equal (equal task distribution required that each friend responded to four of the eight items in a sequence). This distribution error feedback listed the number of responses made by each friend and reminded participants that "Each friend should respond 4 times". Before the preview for the next trial started, participants received a message “Please wait as a new sequence is being prepared” for 1750ms.

The events in each trial were the same in the individual condition with the following exceptions: After each response an individual performed, the key mapping of the button they had pressed was displayed for 500ms. If there was a task distribution error, the error feedback listed the number of responses made per button and reminded participants that “Each button should be pressed 4 times” (see Figure 39).

The 12 sequences were presented in random order in 12 blocks with four repetitions of the same sequence per block. Thus, there were 48 trials in total. The main experiment took participants an average of 13.2 minutes to complete in the individual condition and 19.1 minutes to complete in the imaginary joint condition.

Results

We analysed response errors, task distribution errors, preview time for sequences, and average reaction time to items in a sequence. Furthermore, we analysed the number of switches, and the type of strategy applied in each sequence. One participant in the imaginary joint condition and two participants in the individual condition were excluded from the analyses because their total errors deviated more than three standard deviations from the mean. To compare the Imaginary Joint performance to the actual joint (n = 21 pairs) performance from Study 1 Experiment 1, a random sample of 21 participants was drawn from the Imaginary Joint condition. This sample was used to compare preview time, reaction time, number of switches, and type of strategies used between the two different type of Joint Condition (Imaginary, Actual).

Attempting to achieve a fair task distribution does not necessarily lead to a successful task distribution. Therefore, we included trials in which a fair task distribution was not successful in the analyses of preview times, reaction times, number of switches made, and strategy use. For ambiguous sequences, response error was zero for all participants because either button press was correct under the form or colour response mapping. Within the Ambiguous Mapping condition, participants in the individual condition preferred performing the form task (58.0%) while participants in the imaginary joint condition preferred performing the colour task (65.4%).

Where not indicated otherwise, results were analysed with a 2 x 2 x 3 mixed ANOVA with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factors Task Type (Ambiguous Mapping, Unique Mapping) and Feature Alternation (1, 2, 4).

Response Errors. This measure could only be computed for the Unique Mapping condition, where response errors could be committed. Table 16 displays the error rates.

Table 16

Mean Percentage of Response Errors and Standard Deviations by Condition

Feature Alternation	Individual (*n* = 29)		Imaginary Joint (*n* = 30)	
	M	*SD*	*M*	*SD*
1	1.6	5.1	1.8	4.3
2	2.5	5.1	2.2	4.4
4	1.7	5.3	1.2	2.5

Response errors in both the imaginary joint condition (*M* = 1.7%, *SD* = 2.7%) and individual condition (*M* = 1.9%, *SD* = 3.7%) were low. A mixed 2-way ANOVA with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factor Feature Alternation (1, 2, 4) resulted in no significant main effect of Condition, $F(1, 57) = 0.08$, $p = .778$, $\eta^2 < .01$. There was also no significant main effect of Feature Alternation, $F(2, 114) = 0.91$, $p = .407$, $\eta_p^2 = .02$.

Task Distribution Errors. Table 17 displays the percentage of task distribution errors across the different conditions. There was no effect of Condition, *F*(1, 57) = 1.08, *p* = .302, η^2 = .02. The rate of distribution errors made in the imaginary joint condition (*M* = 2.4%, *SD* = 2.7%) was not any different to that of the individual condition (*M* = 3.2%, *SD* = 2.7%). There were no significant main effects of Feature Alternation, *F*(2, 114) = 2.58, *p* = .080, η_p^2 = .04, Task Type, *F*(1, 57) = 0.08, *p* = .780, η_p^2 < .01, and no significant interactions.

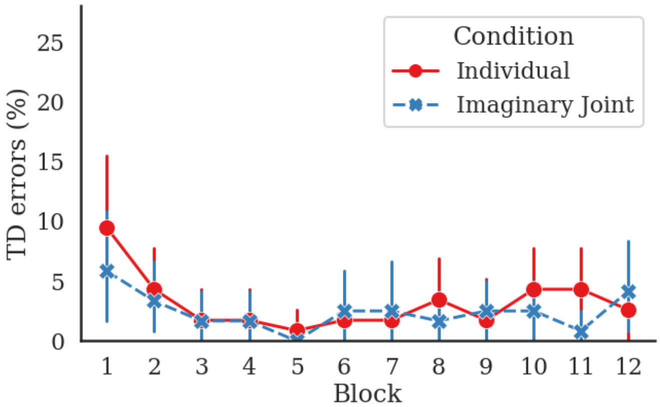
Table 17

Mean Percentage of Task Distribution Errors and Standard Deviations by Condition

Feature Alternation	Individual (*n* = 29)		Imaginary Joint (*n* = 30)	
	M	*SD*	*M*	*SD*
1	1.7	2.8	1.9	3.3
2	3.7	5.4	2.3	3.8
4	4.1	5.6	3.1	5.1

Figure 40

Mean Proportion of Task Distribution Errors Across All 12 Blocks



Note. Error bars are 95% confidence intervals.

An additional Greenhouse-Geisser corrected mixed 2-way ANOVA with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factor Block (1-12) revealed that the proportion of task distribution errors significantly decreased over time, *F*(7.04, 401.18) = 2.61, *p* = .012, η_p^2 = .04. The interaction between Block and Condition was not significant, *F*(7.04, 401.18) = 0.59, *p* = .767, η_p^2 = .01.

Preview Time. Preview Time (PT) was computed as the time interval from the onset of the preview of the sequence until participants pressed a button to indicate that they were ready to respond to the sequence. The mixed 3-way ANOVA revealed only a significant main effect of Task Type, *F*(1, 57) = 6.99, *p* = .011, η_p^2 = .11. Preview times for Ambiguous Mapping sequences (*M* = 3617ms, *SD* = 1948ms) were longer than for Unique Mapping sequences (*M* = 3088ms, *SD* = 1443ms). There were no significant interactions between Task Type and Condition, *F*(1, 57) = 2.79, *p* = .100, η_p^2 = .05. Preview times were not significantly different for participants in the imaginary joint condition (*M* = 3667ms, *SD* = 1749ms) than participants in the individual condition (*M* = 3027ms, *SD* = 1188ms).

Participants in both imaginary joint and individual conditions achieved a faster PT over time. Participants in the imaginary joint condition started out at the first block and ended at the last block with a mean PT of 8300ms (*SD* = 4050ms) and 2417ms (*SD* = 1240ms), respectively. Participants in the individual condition started out at the first block and ended at the last block with a mean PT of 9019ms (*SD* = 6843ms) and 2039ms (*SD* = 1593ms), respectively. A Greenhouse-Geisser corrected mixed ANOVA showed a significant effect of Block on PT, *F*(2.19, 124.83) = 49.72, *p* < .001, η_p^2 = .47, but no interaction between Block and Condition, *F*(2.19, 124.83) = 1.00, *p* = .378, η_p^2 = .02.

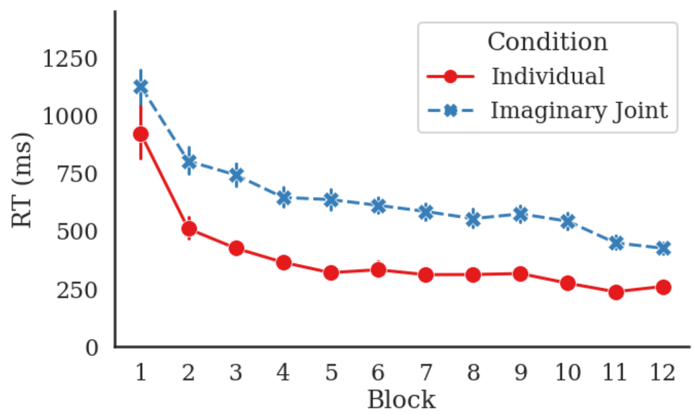
A similar mixed 3-way ANOVA was carried out to see if Task Type, Feature Alternation, or Joint Condition (Imaginary, Actual) affected PT in the imaginary or actual joint mode. There was only a significant difference of Task Type, *F*(1, 40) = 7.33, *p* = .010, η_p^2 = .16. Preview times were generally longer for Ambiguous Mapping sequences (*M* = 4047ms, *SD* = 1921ms) than for Unique Mapping sequences (*M* = 3523ms, *SD* = 1436ms).

Reaction Time. Reaction time (RT) was our measure for the average time participants took to respond to each item in a sequence. The mixed 3-way ANOVA revealed main effects of Task Type, $F(1, 57) = 20.38$, $p < .001$, $\eta_p^2 = .26$, and Condition, $F(1, 57) = 16.38$, $p < .001$, $\eta^2 = .22$. Reaction times for Ambiguous Mapping sequences (*M* = 565ms, *SD* = 324ms) were longer than for Unique Mapping sequences (*M* = 463ms, *SD* = 248ms). Participants in the imaginary joint condition (*M* = 641ms, *SD* = 296ms) were slower than participants in the individual condition (*M* = 382ms, *SD* = 179ms). There were no significant interactions.

A Greenhouse-Geisser corrected mixed ANOVA revealed a significant Block effect on RT, $F(2.89, 164.96) = 34.14$, $p < .001$, $\eta_p^2 = .38$. Participants in the imaginary joint condition started out at the first block and ended at the last block with a mean RT of 1126ms (*SD* = 705ms) and 426ms (*SD* = 178ms) respectively. Participants in the individual condition started out at the first block and ended at the last block with a mean RT of 921ms (*SD* = 673ms) and 261ms (*SD* = 138ms) respectively. The interaction effect of Block and Condition was not significant, $F(2.89, 164.96) = 0.53$, $p = .656$, $\eta_p^2 = .01$.

Figure 41

Mean RT (ms) Across All 12 Blocks



Note. Error bars are 95% confidence intervals.

A similar mixed 3-way ANOVA was carried out to see if Task Type, Feature Alternation, or Joint Condition (Imaginary, Actual) affected RT in the imaginary or actual joint mode. There was a significant difference between imaginary and actual joint condition, $F(1, 40) = 30.56$, $p < .001$, $\eta^2 = .43$. Participants in the imaginary joint condition (*M* = 689ms, *SD* = 316ms) were slower than actual pairs (*M* = 289ms, *SD* = 100ms). There was also a significant effect of Task Type, $F(1, 40) = 9.53$, $p = .004$, $\eta_p^2 = .19$, and a significant interaction between Task Type and Joint Condition, $F(1, 40) = 8.59$, $p = .006$, $\eta_p^2 = .18$. Participants in the imaginary joint condition were slower for Ambiguous Mapping sequences (*M* = 757ms, *SD* = 383ms) than for Unique Mapping sequences (*M* = 620ms, *SD* = 271ms). Actual pairs were less different in RT for Ambiguous Mapping sequences (*M* = 291ms, *SD* = 96ms) and for Unique Mapping sequences (*M* = 287ms, *SD* = 111ms). Feature Alternation had no significant effect on RT, $F(1, 40) = 2.00$, $p = .143$, $\eta_p^2 = .05$.

Switches per Sequence. The number of switches between hands provides a direct measure of how participants distributed tasks. The mixed 3-way ANOVA (Greenhouse-Geisser corrected) revealed no main effects of Condition and Task Type. Feature Alternation, however, had a significant effect on the number of switches, $F(1.17, 66.77) = 287.72$, $p < .001$, $\eta_p^2 = .84$. There was also a significant interaction effect of Feature Alternation and Condition, $F(1.17, 66.77) = 83.72$, $p < .001$, $\eta_p^2 = .60$.

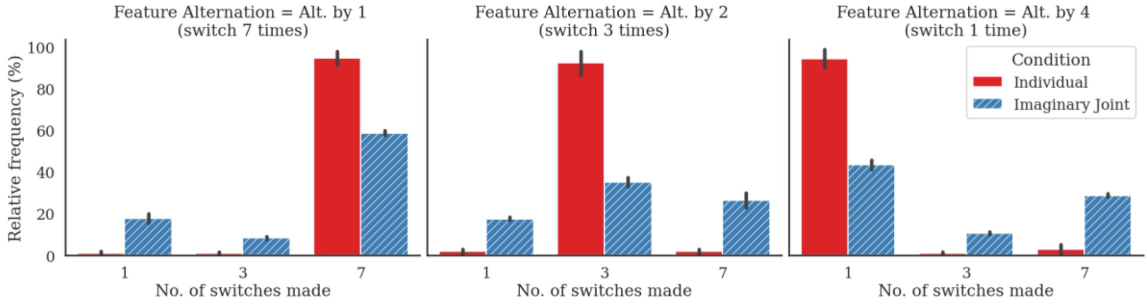
Switches in the individual condition closely followed the switches in perceptual features of the sequence, regardless of task type. When features alternated by one and supported seven switches, participants in the individual condition switched an average of 6.72 (*SD* = .80) times and 6.96 (*SD* = .11) times with the Ambiguous Mapping and Unique Mapping tasks, respectively. When features alternated by two and supported three switches, participants in the individual condition switched an average of 3.11 (*SD* = .45) times and 3.02 (*SD* = .09) times with the Ambiguous Mapping and Unique Mapping tasks, respectively.

When features alternated by four and supported one switch, participants in the individual condition switched an average of 1.43 (*SD* = .79) times and 1.06 (*SD* = .23) times in the Ambiguous Mapping and Unique Mapping tasks, respectively.

In contrast, although there was some indication in the imaginary joint condition that a high number of switches in perceptual features led to a higher number of switches, the differences between levels of alternation were much reduced. When features alternated by one and supported seven switches, participants in the imaginary joint condition switched an average of 5.27 (*SD* = 1.86) times and 5.14 (*SD* = 2.07) times with the Ambiguous Mapping and Unique Mapping tasks, respectively. When features alternated by two and supported three switches, participants in the imaginary joint condition switched an average of 4.1 (*SD* = 1.85) times and 3.90 (*SD* = 1.49) times with the Ambiguous Mapping and Unique Mapping tasks, respectively. When features alternated by four and supported one switch, participants in the imaginary joint condition switched an average of 3.56 (*SD* = 1.99) times and 3.53 (*SD* = 1.81) times with the Ambiguous Mapping and Unique Mapping tasks, respectively.

Figure 42

Relative Frequency of the Number of Switches Made for the Different Levels of Feature Alternation



Note. Error bars are 95% confidence intervals.

Figure 42 plots the relative frequency of the number of switches. Compared to participants in the individual condition, participants in the imaginary joint condition more frequently switched one time per sequence (i.e., minimized turns) or 7 times per sequence (i.e., used turn-taking) across all levels of feature alternation.

Table 18

Partial Eta-squared Effect Size of Feature Alternation x Condition Interaction on Mean Switches for Study 3 Exp1 and Study 1 Exp1*

	Study 3 Exp 1	Study 1 Exp 1
Feature Alternation	.84	.83
Feature Alternation x Condition	.60	.51

**Condition for Study 3 Exp 1 had 30 Imaginary Joint participants and 29 Individual participants. Condition for Study 1 Exp 1 had 21 Pair participants and 21 Individual participants.*

A similar mixed 3-way ANOVA was carried out to see if Task Type, Feature Alternation, or Joint Condition affected how participants switched in the imaginary or actual joint mode. The type of joint condition had a significant effect on the mean number of switches made, $F(1, 40) = 13.26$, $p < .001$, $\eta^2 = .25$. Participants in the imaginary joint condition switched 4.65 (*SD* = 1.48) times on average while pairs in Study 1 Experiment 1 switched 3.03 (*SD* = 1.39) times. Feature Alternation was the only other significant factor on the number of switches made, $F(1.20, 47.85) = 33.37$, $p < .001$, $\eta_p^2 = .46$. On average, participants in both types of joint condition switched 4.56 (*SD* = 1.98) times when features alternated by 1, 3.65 (*SD* = 1.50) times when features alternated by 2, and 3.23 (*SD* = 1.65) times when features alternated by 4. The interaction of Feature Alternation and Joint Condition was not significant, $F(1.20, 47.85) = 0.24$, $p = .669$, $\eta_p^2 = .01$.

Strategy Use. When and where participants switched between hands in a task distribution is indicative of which strategy they use. Using perceptual features as a strategy would imply switching when perceptual features of the sequences alternated while using turn-taking would imply switching after every item. Minimal coordination would be switching once exactly after four items in the sequence. For sequences that alternate by one, turn-taking and use of perceptual features cannot be distinguished. Therefore, these sequences were omitted from the analyses for turn-taking and use of perceptual features. For sequences that alternate by four, use of minimal coordination and use of perceptual features cannot be distinguished. Therefore, these sequences were omitted from the analyses for minimal coordination and use of perceptual features. Thus, only sequences that alternate by two were used for analysis of the perceptual features strategy.

A mixed 2-way ANOVA with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factor Task Type (Ambiguous Mapping, Unique Mapping) was run with only sequences where features alternated by two to examine use of perceptual features as a strategy. There was only a significant main effect of Condition, $F(1, 57) = 73.15$, $p < .001$, $\eta^2 = .56$. Participants in the individual condition switched according to how the sequence alternated 89.9% (*SD* = 15.0%) of the time while participants in the imaginary joint condition switched in the same manner 33.1% (*SD* = 32.5%) of the time. A similar ANOVA was run to compare participants in the Imaginary Joint and Actual Joint conditions. No significant effects were found.

A mixed 3-way ANOVA with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factors Task Type (Ambiguous Mapping, Unique Mapping) and Feature Alternation (2, 4) was run to analyse use of turn-taking as a strategy. There were significant main effects of Condition, $F(1, 57) = 22.50$, $p < .001$, $\eta^2 = .28$, and Task Type, $F(1, 57) = 4.33$, $p = .042$, $\eta_p^2 = .07$. Participants in the individual condition used turn-taking 2.5% (*SD* = 5.0%) of the time while participants in the imaginary joint condition employed turn-taking 27.6% (*SD* = 28.1%) of the time. There was more use of turn-taking with Ambiguous Mapping tasks, 17.2% (*SD* = 23.0%), than with Unique Mapping tasks, 13.3% (*SD* = 26.5%). There was no significant interaction between Condition and Task Type, $F(1, 57) = 0.10$, $p = .756$, $\eta_p^2 < .01$.

A similar ANOVA was run to compare imaginary joint and actual joint conditions. There was a significant effect of Joint Condition, $F(1, 40) = 14.11$, $p < .001$, $\eta^2 < .26$. Participants in the imaginary joint condition (M = 34.7%, SD = 29.7%) used turn-taking more than participants in the actual joint condition (M = 6.9%, SD = 16.4%). No other factors were significant.

A mixed 3-way ANOVA with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factors Task Type (Ambiguous Mapping, Unique Mapping) and Feature Alternation (1, 2) was run to analyse use of minimal coordination as a strategy. There was only a significant main effect of Condition, $F(1, 57) = 13.59$, $p < .001$, $\eta^2 = .19$. Participants in the individual condition used minimal coordination 1.3% (SD = 5.3%) of the time while participants in the imaginary joint condition used minimal coordination 17.3% (SD = 22.8%) of the time. For the additional analysis comparing imaginary joint and actual joint conditions, no significant effects were found.

Discussion

Experiment 1 presents a first attempt to understand the cognitive mechanisms involved when planning a task distribution in an imaginary joint mode and investigated whether they differ from planning for an actual joint task distribution. The results provide first evidence that participants planning for a task distribution in the imaginary joint mode make use of the same turn-taking and minimal coordination heuristics as when planning for an actual joint task distribution. In fact, participants in the imaginary joint mode were using turn-taking more than actual pairs in the previous experiment, providing a strong indication that turn-taking is preferred when distributing a joint task.

Regarding the imaginary joint mode, we predicted that if planning a task distribution for two imaginary partners was similar to planning an actual task distribution, participants in the imaginary joint condition should use turn-taking and minimal coordination heuristics more frequently than participants in the individual condition. This prediction was supported in two ways. First, the number of switches per sequence indicated that participants in the imaginary joint mode were switching at different rates as compared to participants in the individual condition. This difference was likely due to participants in the imaginary joint condition switching one and seven times more frequently than participants in the individual condition. Switching one and seven times, without knowing where in the sequence the switch occurred, would be a first indicator that participants may have been using the minimal coordination and turn-taking heuristics respectively. Importantly, this difference in switching rate between conditions (Figure 42) was similar to that between the actual joint and individual conditions in Study 1 Experiment 1 (Figure 6). Statistical analyses revealed not only similar significant factors across these two experiments but also almost identical effect sizes (Table 18). Participants in both the imaginary joint and the actual joint conditions were frequently switching at a rate different from how features in the sequence alternated. Participants in the individual condition in both this and the previous experiments, however, were switching between hands as often as the items in the task sequence did.

Interestingly, the rate by which features alternated in a sequence had a significant impact on how participants in the imaginary joint and actual joint conditions switched. Specifically, both groups were switching slightly more when features alternated by one as compared to when features alternated by two or four. As features that alternated by one supported turn-taking, and the use of turn-taking would indeed result in a higher switching rate between partners, this increased switching between partners likely reflect more use of turn-taking as opposed to the minimal coordination heuristic. Mean number of switches alone cannot reveal which strategy was used, however. It is clear though, that participants in both the imaginary and actual joint conditions do not rely exclusively on perceptual features for their task distributions, and were both similarly affected by the task features that they were switching slightly more when features alternated by one and supported turn-taking.

A second indication that planning in the imaginary joint mode is similar to planning for an actual joint task comes from the results on strategy use. Coding for when and where exactly participants switched between hands in a sequence, we find that participants in the imaginary joint condition used significantly more of minimal coordination and turn-taking heuristics than participants in the individual condition. Instead, participants in the individual condition were relying almost exclusively on the use of perceptual features in their task distribution, a finding that replicates the results we have seen in Study 1 Experiment 1 and in further studies (see Study 1 Experiment 2 and Study 2).

There were, however, slight differences in strategy use between participants in the imaginary joint condition and participants in the actual joint condition from the previous study. In Study 1 Experiment 1, while pairs were numerically using more turn-taking than individuals, this difference was not statistically significant. In this experiment, however, not only was the difference in turn-taking use between conditions significant, participants in the imaginary joint condition were also using turn-taking at a significantly greater frequency than actual pairs did in Study 1 Experiment 1. Considering that participants are free to enact the best laid plan for a task distribution when in the imaginary joint mode, these differences suggest that when it comes to joint task distributions, turn-taking was the strategy of choice.

Another finding not obtained previously with actual pairs is the general increased use of turn-taking when distributing ambiguous task sequences. In this experiment, participants in both conditions made more frequent use of turn-taking when tasks were ambiguous. Indeed, turn-taking is not only universal (Stivers et al., 2009) and applicable across many different situations (Berkes, 1986; Leo, 2017; Levinson, 2016), but can also be particularly helpful when perceptual features of the tasks are ambiguous and difficult to distribute using a featural order. As results from the preview time analyses indicate, ambiguous task sequences were more difficult to plan for than unique task sequences. Use of turn-taking in this case, would have helped participants achieve a fair task distribution much more easily.

There was, however, no further indication from the planning time analyses that participants in the imaginary joint condition were thinking about potential coordination problems. While there was a numerical difference in planning time between conditions that suggests that participants in the imaginary joint condition may have been simulating potential coordination problems, this difference was not significant. Instead, participants in the imaginary joint condition responded significantly slower than participants in the individual condition. One possible reason for this could be that participants in the imaginary joint condition were thinking about the potential coordination problems only at the time of their response. However, if participants were indeed only considering the coordination problems at the response stage, we should expect to see an interaction between the task type and conditions. Participants in the imaginary joint condition would not only have to consider more possible actions as compared to participants in the individual condition, but twice as many when task sequences are ambiguous. This interaction effect was not observed in the reaction time analyses.

There was, however, an interaction between task type and joint conditions for reaction time. Participants in the imaginary joint condition were slower on ambiguous mapping sequences than on unique sequences while participants in the actual joint condition were not much different on either. While this difference could also be attributed to participants in the imaginary joint condition considering their potential actions only at the response stage, we think this result is more likely driven by actual pairs speeding up their responses to facilitate joint action (Vesper et al., 2016, 2009). Participants in the imaginary joint condition naturally had no need for such strategy.

A second possible reason for the reaction time difference between imaginary joint and individual task distributions can be attributed to the different number of response buttons per condition. Participants in the imaginary joint condition had to manage four response buttons throughout the experiment while participants in the individual condition only had to manage two. Similarly, participants in the actual joint condition had to manage only two buttons. Future experiments should find ways to equalize the number of response alternatives participants have to handle each time.

All in all, the differences observed between conditions in the current experiment provide a good starting point for understanding better the mental contents of a plan. Despite performing a task individually in both conditions, participants instructed to distribute a task between two imaginary partners were doing it no differently from the way actual pairs would. The clear use of both minimal coordination and turn-taking heuristics strongly suggests that the imaginary joint condition is an effective manipulation and a good proxy for inducing the same task distribution heuristics that are used in actual joint action.

Experiment 2

As a second test of the imaginary joint action method, we used Experiment 2 from the second study (Chapter 2: Procedural and Distributive Fairness in a Joint Task Distribution) that was designed to assess how distributive fairness in terms of effort affects the use of a fair procedure in the task distribution process. Specifically, we were interested to find out if distributive fairness affects the use of a fair procedure in the imaginary joint mode the same way it would in an actual joint task distribution. In the previous experiment with actual pairs, we found that although distributive fairness might have been a concern when planning a task distribution, the fair procedure of turn-taking was used even when it led to an unequal distribution of effort between partners. In fact, turn-taking was used even if a second fair procedure (i.e., minimal coordination) was available and led to an equal distribution of effort between partners more often than turn-taking. Additionally, pairs were increasingly using perceptual features to distribute the task. Use of perceptual features was a strategy that unmistakably led to an unequal distribution of effort as different colours were used to represent the different effort requirements of the subtasks.

If distributive fairness has no impact on how fair procedures are used in the imaginary joint mode, participants in the imaginary joint condition should rely on procedural fairness and use turn-taking more than participants in the individual condition. This should be the case even if use of turn-taking does not lead to distributive fairness. However, if achieving distributive fairness is important for a task distribution in the imaginary joint mode, participants distributing a task in the imaginary joint condition should use strategies that ensure an equal distribution of effort. In this case, minimal coordination is one strategy that should be used more than turn-taking as minimal coordination would ensure an equal distribution of effort more often than turn-taking.

Method

Participants. Sixty-one participants (33 females, age range 19 – 44 years) were recruited through the university's SONA system and a student organization. Thirty participants were assigned to the individual condition and 31 participants were assigned to the imaginary joint condition. Participants were reimbursed with vouchers worth 1500 Hungarian forints or 1500 Hungarian forints in cash. All participants reported at least conversational skill in English and normal colour vision. The experimental protocol was approved by the United Ethical Review Committee for Research in Psychology, Hungary.

Material and Apparatus. In the individual condition, a 22-inch monitor was set on the table about 50cm away from where the participant was seated. On the table between the monitor and the participant was the controller box with four white circular buttons. Only the two outer buttons were used in the experiment. Participants in the individual condition had control over the two buttons used in the experiment. In the imaginary joint condition, the two buttons were split across two similar controller boxes such that only the outermost left button was used on the left controller box and the outermost right button was used on the right controller box. The experiment was programmed using E-prime 2.0 on the Windows 7.0 Professional operating system and run on a Dell Precision, T5610.

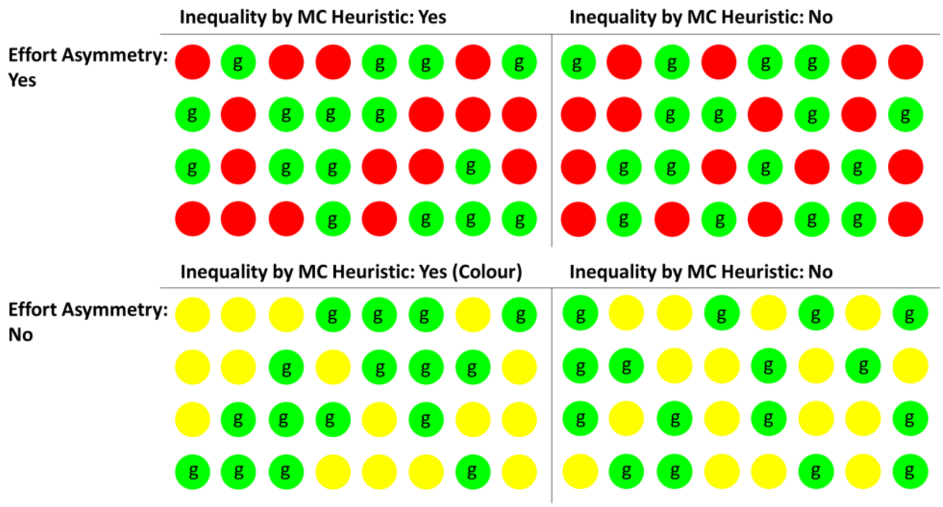
Figure 43 displays the sixteen different stimulus sequences used in Experiment 2. All sequences consisted of eight items that required eight separate responses. Green and yellow circles each required one press for a valid response. Red circles required four presses of the same button for a valid response. Each sequence consisted of circles in two colours, either green and yellow, or green and red. The items in these sequences were arranged such that when there was an effort asymmetry present, an equal distribution where partners put in an equal amount of effort would be achievable by use of the minimal coordination heuristic, or not at all.

For all eight sequences with effort asymmetry, an equal distribution would be one where each friend in the imaginary joint condition (or each hand, as in the individual condition) responds to a total of two red circles and two green circles. This equal distribution can be achieved easily via use of the minimal coordination heuristic for half of these sequences (see the four sequences in the top right cell of Figure 43). For the other half of these sequences (see the four sequences in the top left cell of Figure 43), an equal distribution cannot be achieved via the minimal coordination and turn-taking heuristics but only through any other strategy that distributes two red items and two green ones to each partner (or hand).

The projected percentages of equal effort distributions by use of the different strategies remain the same as with Chapter 2, Experiment 2 (see Table 12).

Figure 43

Stimulus Sequences Used in Experiment 2

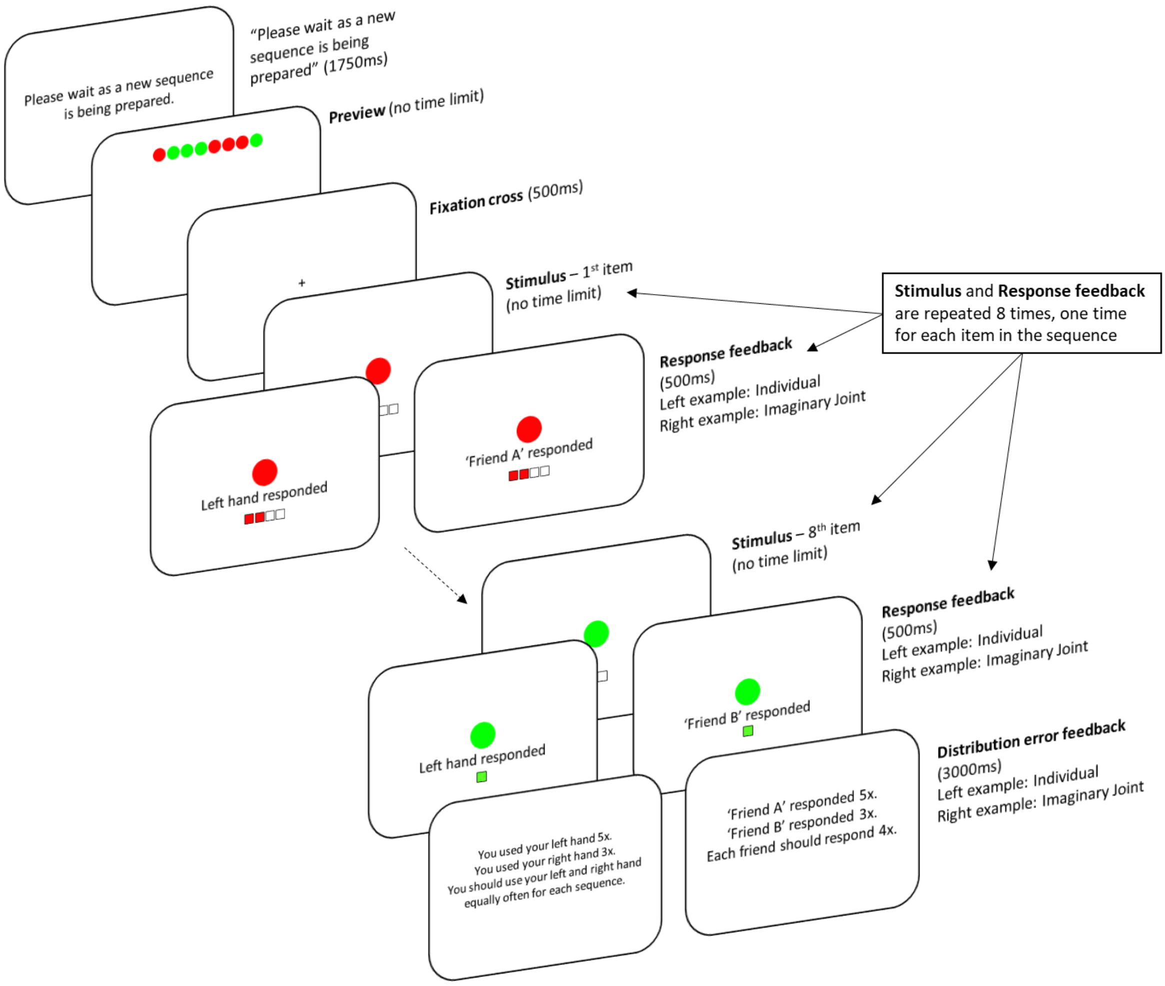


Note. For purpose of contrast on monochrome displays, items labelled with 'g' are green in colour. Items not labelled in the first row (Effort Asymmetry: Yes) are red in colour while items not labelled in the second row (Effort Asymmetry: No) are yellow in colour. No labels were used in the actual experiment. For all eight sequences in the top row, use of the turn-taking heuristic would surely result in inequality. MC Heuristic = Minimal Coordination Heuristic.

Procedure. Apart from introducing the different effort requirement in the stimulus sequences, procedure and sequence of events for each trial were kept the same as in Experiment 1 of this study. The 16 sequences were also presented in random order in 16 blocks with four repetitions of the same sequence per block. Thus, there were 64 trials in total. As before, the first four blocks of the experiment comprised two sequences with effort asymmetry and two sequences without effort asymmetry, each randomly picked from the total 16 sequences (see Figure 43). Of these four sequences, one sequence with effort asymmetry and one sequence without effort asymmetry led to an unequal distribution via use of the minimal coordination heuristic. The remaining two sequences led to an equal distribution via use of the minimal coordination heuristic. The following four blocks similarly comprised the four different sequence types. This arrangement carried on throughout the experiment until all 16 sequences were presented in 16 blocks. The main experiment took participants an average of 26.7 minutes in the individual condition and 27.1 minutes in the imaginary joint condition to complete.

Figure 44

Sequence of Events For Each Trial in Experiment 2



Results

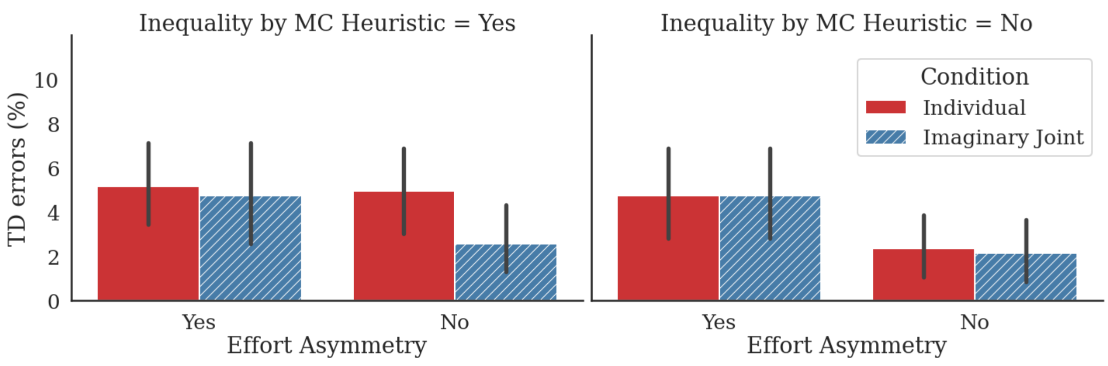
Besides excluding response errors and including frequency of unequal effort distributions in our analysis, all other measures were kept the same as in Experiment 1, of this current study. Response errors were not possible here as every item in this experiment required only one type of response throughout. Unlike in Experiment 1, there were no different response keys needed for responding to form and colour in this experiment. Instead, because some items required participants to press the same button more than once, participants may end up with an unequal distribution of effort where one hand presses the button more than the other.

Where not indicated otherwise, results were analysed with a 2 x 2 x 2 mixed ANOVA with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factors Effort Asymmetry (Yes, No) and Inequality by MC Heuristic (Yes, No). One participant from the imaginary joint condition was excluded from the analyses due to experimenter error. Another participant from the imaginary joint condition and one participant from the individual condition were excluded from the analyses because their distribution errors deviated more than three standard deviations from the mean. While the experiment here was based on Experiment 2 in Study 2, direct comparisons between the imaginary and actual joint conditions are impossible as the stimulus sequence sets used were different. In Study 2 Experiment 2 with actual pairs, the final dataset included measures from only 12 sequences. This was due to a sequence discovered to be added wrongly after data collection was done. In this current experiment, the sequence previously added wrongly was replaced and all 16 sequences were used and analysed.

Task Distribution Errors. The task distribution error rate was low and did not differ significantly between the individual (M = 4.6%, SD = 3.2%) and the imaginary joint (M = 4.1%, SD = 4.4%) conditions, $F(1, 56) = 0.76$, $p = .387$, $\eta^2 = .01$. There was only a significant main effect of Effort Asymmetry, $F(1, 56) = 8.31$, $p = .006$, $\eta_p^2 = .13$. More task distribution errors were made when an effort asymmetry was present (M = 4.9%, SD = 4.8%) than when none was present (M = 3.0%, SD = 3.2%). There was no significant interaction between Condition and Effort Asymmetry, $F(1, 56) = 0.72$, $p = .400$, $\eta_p^2 = .01$. There was also no effect of Inequality by MC Heuristic, $F(1, 56) = 1.98$, $p = .165$, $\eta_p^2 = .03$, nor of an interaction between Condition and Inequality by MC Heuristic, $F(1, 56) = 1.11$, $p = .296$, $\eta_p^2 = .02$. There was, however, a significant effect of Effort Asymmetry on task distribution errors for participants in the imaginary joint condition only, $t(28) = -2.40$, $p = .023$, $d = -0.45$. Like in Study 2 Experiment 1, more task distribution errors were made when an effort asymmetry was present, (M = 4.7%, SD = 5.6%), than when it was not, (M = 2.4%, SD = 3.4%).

Figure 45

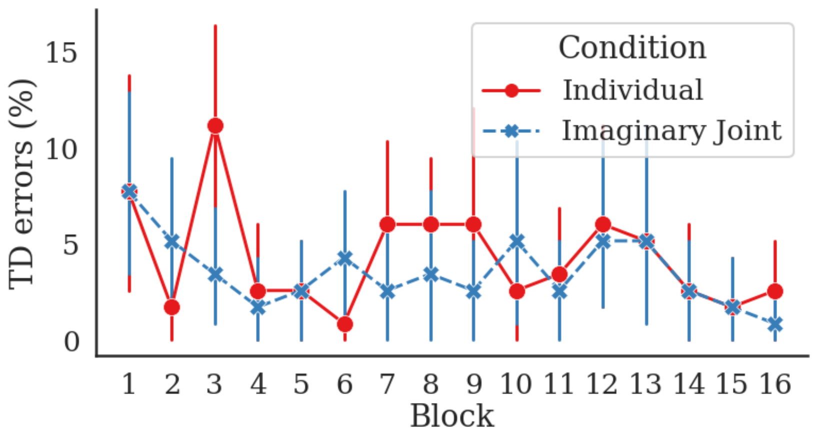
Mean Percentage of Task Distribution Errors Across Factors



Note. Error bars are 95% confidence intervals.

Figure 46

Mean Proportion of Task Distribution Errors Across All 16 Blocks



Note. Error bars are 95% confidence intervals.

An additional Greenhouse-Geisser corrected mixed 2-way ANOVA with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factor Block (1-16) revealed that the proportion of task distribution errors significantly decreased over time, $F(10.47, 586.18) = 2.04$, $p = .026$, $\eta_p^2 = .04$. The interaction was not significant, $F(10.47, 586.18) = 1.17$, $p = .304$, $\eta_p^2 = .02$.

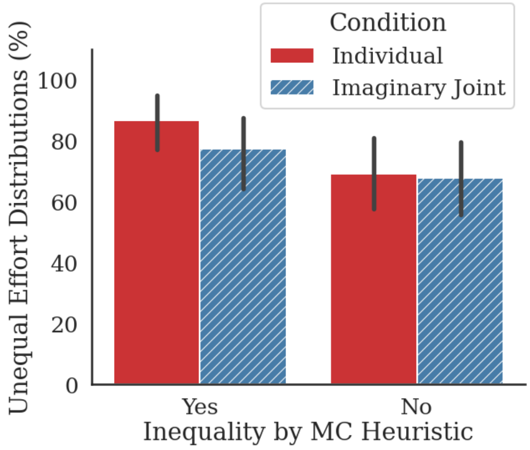
Unequal Effort Distributions. An unequal distribution of the total number of button presses between the two hands of a person in a sequence was considered an unequal effort distribution. In sequences with effort asymmetry, a total of 20 button presses were required for the eight items in each sequence. Thus, an equal distribution of 20 presses would be 10 presses per hand. Any other distribution was considered an Unequal Effort Distribution. In sequences without effort asymmetry, the total number of button presses required was eight, the same as the number of items in the sequence. These errors are covered by Task Distribution Errors above and will not be included in this section here.

A mixed 2-way ANOVA with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factor Inequality by MC Heuristic (Yes, No) revealed only a main effect of Inequality by MC Heuristic, $F(1, 56) = 17.67$, $p < .001$, $\eta_p^2 = .24$. There were more unequal effort distributions when an equal distribution was not possible by the minimal coordination heuristic ($M = 82.0\%$, $SD = 30.2\%$) than when an equal distribution was possible ($M = 68.5\%$, $SD = 33.6\%$). There was no significant difference in frequency of unequal effort distributions between conditions, $F(1, 56) = 0.46$, $p = .500$, $\eta^2 = .01$. Participants in the imaginary joint condition made an average of 72.6% ($SD = 34.2\%$) unequal effort distributions while participants in the individual condition made an average of 77.9% ($SD = 30.8\%$). There was no significant interaction between Condition and Inequality by MC Heuristic, $F(1, 56) = 1.55$, $p = .219$, $\eta_p^2 = .03$.

A Huynh-Feldt corrected mixed 2-way ANOVA was run with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factor Quartiles (1-4). Proportion of unequal effort distributions did differ overtime for participants in both conditions, $F(2.30, 128.79) = 3.17$, $p = .039$, $\eta_p^2 = .05$.

Figure 47

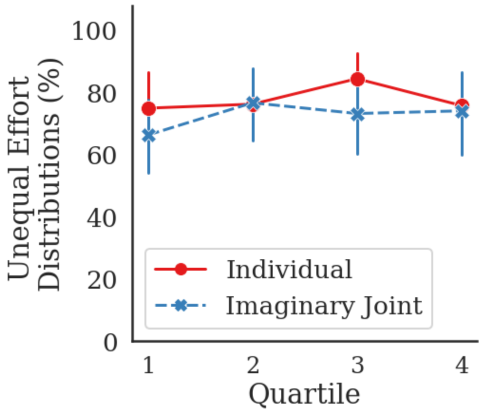
Mean Percentage of Unequal Effort Distributions Across Inequality by MC Heuristic



Note. Error bars are 95% confidence intervals.

Figure 48

Mean Percentage of Unequal Effort Distributions Across All Quartiles

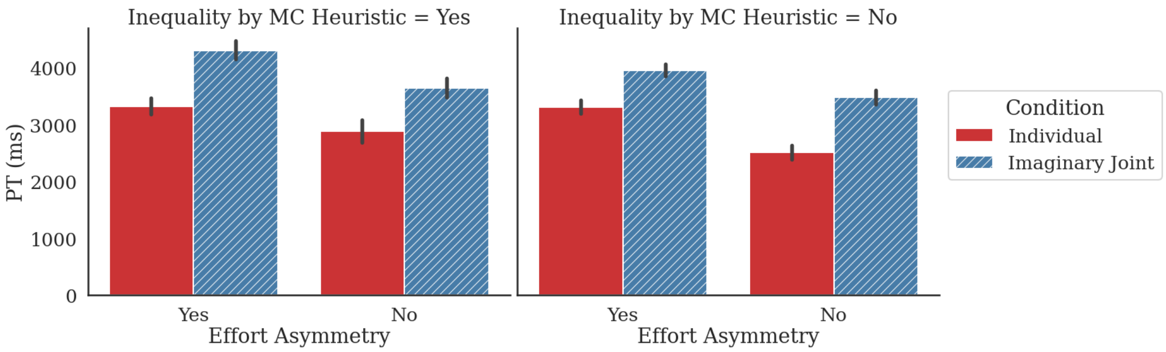


Note. Error bars are 95% confidence intervals.

Preview Time. There was only a significant main effect of Effort Asymmetry, $F(1, 56) = 7.08$, $p = .010$, $\eta_p^2 = .11$. In general, preview times were longer for sequences with effort asymmetry (M = 3723ms, SD = 2144ms) than for sequences with no effort asymmetry (M = 3129ms, SD = 1861ms). There were no significant effects of Condition, $F(1, 56) = 3.19$, $p = .080$, $\eta^2 = .05$, and Inequality by MC Heuristic, $F(1, 56) = 0.92$, $p = .341$, $\eta_p^2 = .02$. There were also no significant interactions of Condition and Effort Asymmetry, $F(1, 56) = 0.01$, $p = .906$, $\eta_p^2 < .01$, and of Condition and Inequality by MC Heuristic, $F(1, 56) = 0.02$, $p = .884$, $\eta_p^2 < .01$.

Figure 49

Mean PT (ms) Across All Factors



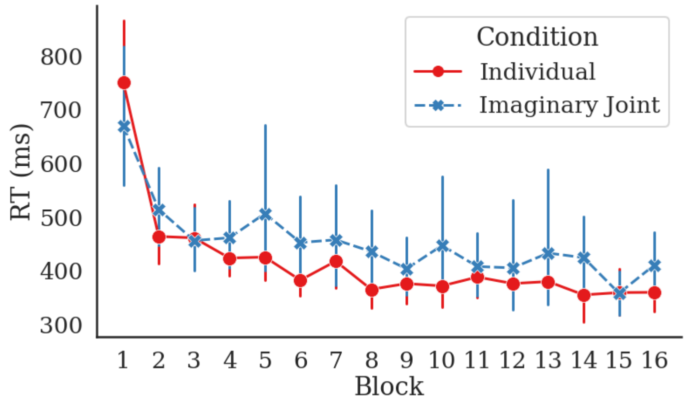
Note. Error bars are 95% confidence intervals.

Participants in both conditions achieved a faster PT over time. A Greenhouse-Geisser corrected mixed ANOVA showed a significant effect of Block on PT, $F(4.54, 254.27) = 35.92$, $p < .001$, $\eta_p^2 = .39$, but no interaction between Block and Condition, $F(4.54, 254.27) = 1.05$, $p = .387$, $\eta_p^2 = .02$. Participants in the imaginary joint condition started out at the first block and ended at the last block with a mean PT of 10,259ms (SD = 4882ms) and 2106ms (SD = 1256ms), respectively. Participants in the individual condition started out at the first block and ended at the last block with a mean PT of 10,883ms (SD = 7797ms) and 1629ms (SD = 1139ms), respectively.

Reaction Time. There were no effects of Effort Asymmetry, $F(1, 56) = 3.63$, $p = .062$, $\eta_p^2 = .01$, and none of Inequality by MC Heuristic, $F(1, 56) = 1.83$, $p = .181$, $\eta_p^2 < .01$. There was also no significant difference between conditions, $F(1, 56) = 0.77$, $p = .385$, $\eta^2 = .01$. A Greenhouse-Geisser corrected mixed ANOVA with the between-subject factor Condition (Individual, Imaginary Joint) and the within-subject factor Block (1-16) revealed a significant Block effect on RT, $F(4.32, 242.13) = 22.37$, $p < .001$, $\eta_p^2 = .29$. Participants in the imaginary joint condition started out at the first block and ended at the last block with a mean RT of 670ms (*SD* = 352ms) and 409ms (*SD* = 159ms), respectively. Participants in the individual condition started out at the first block and ended at the last block with a mean RT of 751ms (*SD* = 311ms) and 359ms (*SD* = 103ms), respectively. There was no significant interaction effect of Block and Condition, $F(4.32, 242.13) = 1.40$, $p = .231$, $\eta_p^2 = .02$.

Figure 50

Mean RT (ms) Across All 16 Blocks



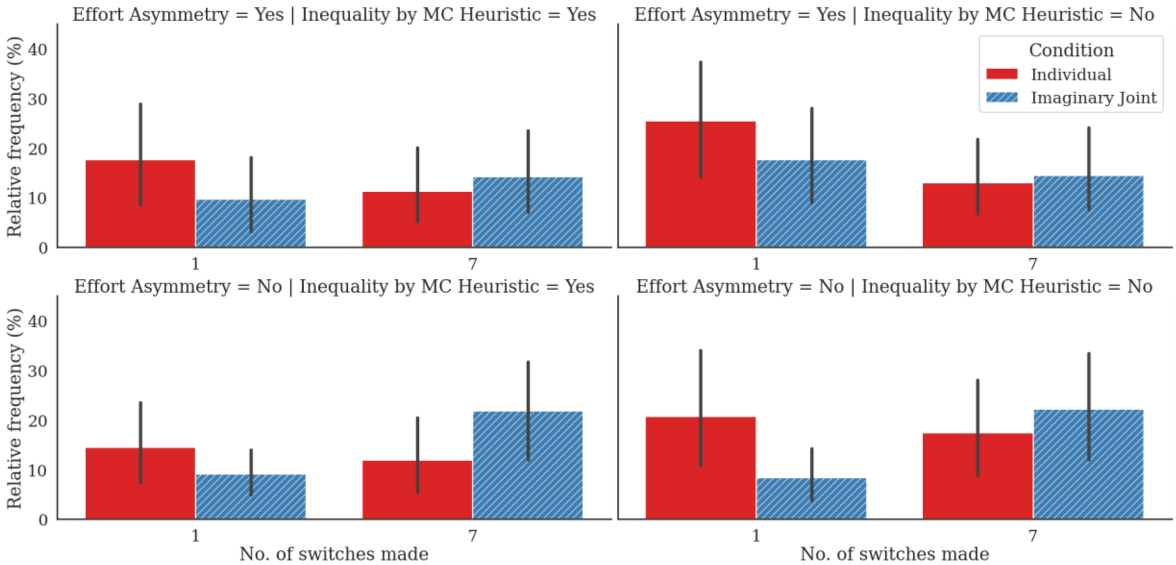
Note. Error bars are 95% confidence intervals.

Switches per Sequence. There were no main effects of Effort Asymmetry, $F(1, 56) = 0.99$, $p = .324$, $\eta_p^2 = .02$, nor of Condition, $F(1, 56) = 2.08$, $p = .154$, $\eta^2 = .04$. Inequality by MC Heuristic, however, had a significant effect on the number of switches, $F(1, 56) = 41.63$, $p < .001$, $\eta_p^2 = .43$. More switches were made when an equal distribution by the minimal coordination heuristic was possible (*M* = 4.6, *SD* = 1.4) than when an equal distribution by

MC was not possible (*M* = 3.9, *SD* = 1.0). There was also a significant interaction between Inequality by MC Heuristic and Effort Asymmetry, $F(1, 56) = 23.05$, $p < .001$, $\eta_p^2 = .29$. Incidentally, the mean number of switches by the different levels of Inequality by MC Heuristic were comparable to the average number of switches should perceptual features be used as a strategy throughout. For the eight sequences where an equal distribution by the MC heuristic was possible, consistently using perceptual features would result in an average of 5.5 switches. For the other eight sequences where an equal distribution by the MC heuristics was not possible, consistently using perceptual features would result in an average of 3.8 switches. Which strategy was actually used however, cannot be derived from just the number of switches made per sequence. When and where participants switched in a sequence would be a more accurate indicator of which strategy was used. This is covered in the next section, Strategy Use.

Figure 51

Relative frequency of the Number of Switches Across All Factors



Note. Error bars are 95% confidence intervals.

Table 19

Mean Number of Switches by Inequality by MC Heuristic and Effort Asymmetry

Effort Asymmetry	Inequality by MC Heuristic			
	Yes		No	
	M	*SD*	*M*	*SD*
Yes	4.0	1.1	4.5	1.5
No	3.8	1.0	4.9	1.3

Strategy Use. For turn-taking (TT), there was no effect of Condition, $F(1, 56) = 0.69$, $p = .409$, $\eta^2 = .01$, nor of Inequality by MC Heuristic, $F(1, 56) = 3.92$, $p = .053$, $\eta_p^2 < .01$. Only Effort Asymmetry had a significant effect, $F(1, 56) = 4.30$, $p = .043$, $\eta_p^2 = .01$. There was more turn-taking observed when there was no effort asymmetry (*M* = 18.3%, *SD* = 26.2%) than when effort asymmetry was present (*M* = 13.2%, *SD* = 21.2%). There was also no significant interaction between Effort Asymmetry and Condition, $F(1, 56) = 1.05$, $p = .309$.

Table 20

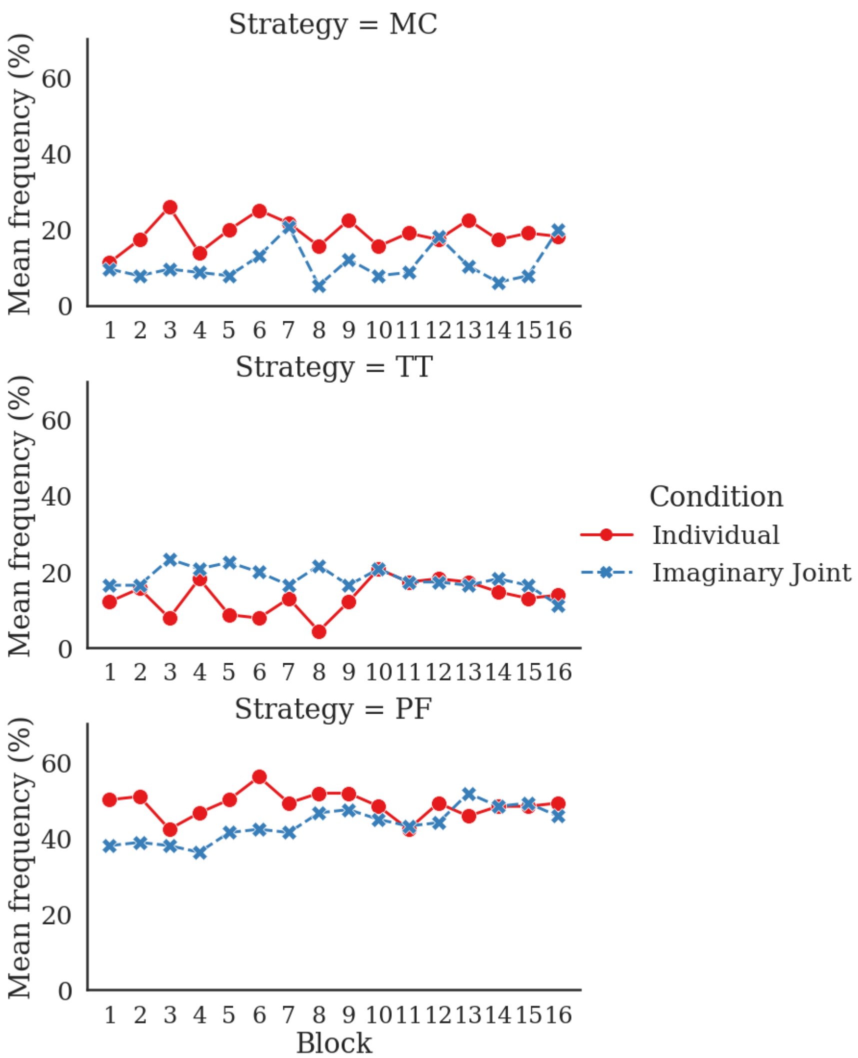
Percentage of Strategy Use by Condition

Strategy	Individual		Imaginary Joint	
	M	*SD*	*M*	*SD*
Turn-taking	12.8	19.5	16.5	22.8
Minimal Coordination	19.4	25.3	11.7	16.7
Perceptual Features	48.1	34.1	42.8	35.8

For minimal coordination (MC), there was no difference between Condition, $F(1, 56) = 2.22$, $p = .142$, $\eta^2 = .04$. There were, however, significant effects of both Inequality by MC Heuristic, $F(1, 56) = 4.39$, $p = .041$, $\eta_p^2 = .07$, as well as Effort Asymmetry, $F(1, 56) = 4.87$, $p = .031$, $\eta_p^2 = .08$. There was more use of minimal coordination when an effort asymmetry was present (*M* = 16.5%, *SD* = 23.1%) than when there was no effort asymmetry (*M* = 13.1%, *SD* = 19.9%). There was also more use of minimal coordination when it led to an equal distribution (M = 18.5%, SD = 25.9%) than when it did not (M = 12.5%, SD = 21.4%). The interaction of Inequality by MC Heuristic and Effort Asymmetry was not significant, $F(1, 56) = 3.32$, $p = .074$, $\eta_p^2 = .06$. There was also no significant interaction between Condition and Effort Asymmetry, $F(1, 56) = 0.14$, $p = .710$, $\eta_p^2 < .01$, nor between Condition and Inequality by MC Heuristic, $F(1, 56) = 0.36$, $p = .554$, $\eta_p^2 = .01$.

Figure 52

Mean Frequency (%) of Strategy Use by Block



Note. MC = Minimal Coordination; TT = Turn-taking; PF = Perceptual Features.

For use of perceptual features (PF), there was no significant effect of Condition, $F(1, 56) = 0.32$, $p = .576$, $\eta_p^2 = .01$, Inequality by Heuristic, $F(1, 56) = 0.33$, $p = .566$, $\eta_p^2 = .01$, nor of Effort Asymmetry, $F(1, 56) = 3.04$, $p = .087$, $\eta_p^2 = .05$. There were, however, significant interaction effects between Inequality by MC Heuristic and Condition, $F(1, 56) = 4.25$, $p = .044$, $\eta_p^2 = .07$, and between Inequality by MC Heuristic, Effort Asymmetry, and Condition, $F(1, 56) = 4.32$, $p = .042$, $\eta_p^2 = .07$. Participants in the imaginary joint condition used perceptual features more when Inequality by MC Heuristic was possible (*M* = 44.2%, *SD* = 35.7%) than when it was not (*M* = 41.4%, *SD* = 35.7%). By comparison, participants in the individual condition used perceptual features no differently whether an equal distribution by MC heuristic was possible (*M* = 47.7%, *SD* = 35.0%) or not (*M* = 48.1%, *SD* = 34.5%). Means and standard deviations for the three-way interaction can be found in Table 21 for participants in the individual condition and Table 22 for participants in the imaginary joint condition.

Table 21

Mean Percentage of Perceptual Features Use by All Factors for Participants in the Individual Condition

Effort Asymmetry	Inequality by MC Heuristic			
	Yes		No	
	M	*SD*	*M*	*SD*
Yes	46.8	36.0	47.6	35.8
No	52.6	34.9	47.8	37.1

Table 22

Mean Percentage of Perceptual Features Use by All Factors for Participants in the Imaginary Joint Condition

Effort Asymmetry	Inequality by MC Heuristic			
	Yes		No	
	M	*SD*	*M*	*SD*
Yes	40.9	35.5	42.7	36.5
No	42.7	37.5	47.8	37.2

The use of perceptual features within a sequence can also be combined with the use of turn-taking and minimal coordination across the four repeated trials of the same sequence. In this case, for example, using perceptual features within a sequence and using turn-taking across the four trials would be one hand responding to all the high-effort red items for the first and third trials while the other hand responds to all the red items in the second and forth trials. Minimal coordination would be one hand responding to all the high-effort red items in the first two trials before switching over to the other hand to respond to all the red items for the last two trials. Importantly, combining the use of perceptual features within a sequence and the use of heuristics across trials can lead to an overall equal distribution of effort.

To check if achieving overall distributive fairness is important for a task distribution in the imaginary joint mode, we tabulated the number of times perceptual features were used in combination with turn-taking or minimal coordination strategies across trials. To run this analysis, we took only data from participants who used perceptual features for all four trials of any sequence. This subset of data comprised 18 participants in the individual condition and 15 participants in the imaginary joint condition.

A score of 1 was coded on every sequence if minimal coordination or turn-taking heuristics was used across trials. If there was no use of heuristics across trials, a score of 0 was given. Participants in the imaginary joint condition (M = 34.2%, SD = 45.4%) used heuristics across the four trials in a block significantly more often than participants in the individual condition (M = 6.4%, SD = 12.3%), $t(15.7) = -2.31$, $p = .035$, $d = -0.84$ (corrected for unequal variances).

Discussion

Experiment 2 asked if distributive fairness affects the use of a fair procedure in the imaginary joint mode the same way it would with an actual joint task distribution. Results from this experiment show that distributive fairness is important between partners even in an imaginary joint condition and can affect the way fair procedures are used in a task distribution.

A prediction made was that if achieving distributive fairness is important for task distribution in the imaginary joint mode, participants distributing a task in the imaginary joint condition should use strategies that ensure an equal distribution of effort. For this experiment, this would mean using minimal coordination more than turn-taking since use of minimal coordination would result in an equal distribution of effort for each task sequence more often than turn-taking. While there was no such indication that participants in the imaginary joint condition were using minimal coordination to ensure an equal distribution of effort for each sequence, there was evidence for a combination of strategies that participants were using to ensure an equal distribution of effort overall. This combination of strategies involved using perceptual features within a sequence and turn-taking or minimal coordination heuristics across the four repeated trials of the same sequence. This meant that one partner was responding to all the difficult high-effort items for two trials and then switching over to the easy low-effort items for the other two trials. This switch happened either after every trial via turn-taking or after two consecutive trials via minimal coordination. Importantly, this combination of strategies that would ensure an overall equal distribution of effort was observed only with participants in the imaginary joint condition.

This combination of strategies observed here also provides additional insight regarding the findings in Study 2 Experiment 2. Previously, the strategy that pairs used most frequently after turn-taking was relying on perceptual features. While the use of turn-taking could be attributed to pairs relying on procedural fairness in their task distributions, the use of perceptual features was a little less understood. Given the current results, it is possible that like the participants in the imaginary joint condition, pairs were also attempting to use perceptual features in combination with turn-taking or minimal coordination heuristics across trials to ensure an equal distribution of effort overall. However, because partners were not allowed to talk to each other and were interacting on the same tasks from separate rooms, successfully implementing this combination of strategies was a lot more difficult for them compared to participants in the imaginary joint. For participants in the imaginary joint condition, implementing the combined use of perceptual features and turn-taking or minimal coordination heuristics would be much easier since the eventual distribution is after all coordinated by one person only. This interpretation would be in line with the finding in Study 2, where ease of implementing a certain task distribution is an important factor for how a fair task distribution is eventually achieved.

General Discussion

This study was a first test of using an imaginary joint action method to assess strategies in joint action planning. Specifically, we conducted two experiments that were previously run with actual pairs and asked if planning for a task distribution in the imaginary joint mode would be similar to planning an actual joint task distribution. In two experiments, we found that the imaginary joint condition can not only function as an effective proxy for studying the joint action mode but also that distributive fairness can indeed guide the use of a fair procedure when not limited by the potential coordination problems that arise from an actual joint task distribution.

In both experiments, even though participants in both conditions were technically performing the same task with two hands, participants in the imaginary joint condition were behaving systematically differently from participants in the individual condition. Participants in the imaginary joint condition were planning task distributions using strategies that were not only different from those used by participants in the individual condition, but that resembled strategies that were previously associated with actual joint task distributions.

The novel use of the imaginary joint action method was especially fruitful in the second experiment. In the previous Study 2 Experiment 2, while pairs were still using turn-taking, they were also increasingly using perceptual features for their task distributions. With this imaginary joint action method, we were able to assess the best laid plans that partners may have had for a fair task distribution and gain a fuller picture of how perceptual features could have been used to ensure distributive fairness. Importantly, we found that distributive fairness can indeed guide the use of a fair procedure and that this is likely dependent on how easy it is to achieve distributive fairness. When achieving an equal distribution of effort was difficult in an actual joint task distribution, partners relied on procedural fairness. When achieving an equal distribution of effort between partners was without the potential obstacles that come in an actual joint task distribution, the choice of procedure and how it was used in distributing the task was clearly guided by distributive fairness.

It is possible though, that if the pairs in the previous studies had comprised actual friends the same way partners in the imaginary joint condition were made up of a pair of friends, the results for Study 2 Experiment 2 might have been different. Research has shown that familiarity with one’s partner can help to smooth performance of joint action tasks considerably (Wegner et al., 1991). It remains to be seen if an actual pair comprising actual friends would be more successful at the combination of strategies that would ensure distributive fairness, or if they would rely on procedural fairness the same way pairs of strangers did in the previous study. It would also be interesting to explore if planning in the imaginary joint mode for a pair of strangers is any different to planning for a pair of friends.

In sum, this study finds that planning for a task distribution in the imaginary joint mode is comparable to planning for an actual joint task distribution. The imaginary joint condition is not only an effective method for understanding the planning process of a joint task distribution but also a promising technique for exploring social cognition within an individual. By simply comparing participants in the imaginary joint mode with actual pairs, what has emerged is a fuller and more insightful picture of the cognitive processes involved in task distribution.

Concluding Discussion

In this thesis, we asked what the cognitive mechanisms involved in planning fair task distributions are. We reviewed the literature and found that joint actions between partners are commonly arranged in two formats. In the first approach, partners make use of a temporal order and coordinate their actions according to when they should act. In the second, partners focus on the features of the task and coordinate by separating out the different parts of the task that each partner will act on. Regardless of which of the two approaches, partners would likely also be concerned about how to fairly distribute the task among themselves such that no one does more or less than the other. By comparing joint performance to individual performance and with two new methods, we aimed to measure not only the amount of mental effort required but also to infer the different cognitive mechanisms involved in planning a joint task distribution. We focused on mentalizing, use of heuristics, and use of perceptual features as three cognitive mechanisms involved in planning task distributions. We also investigated the role of fairness when planning task distributions. Specifically, we ask how fairness of procedure and fairness of distribution of effort can differently affect the task distribution process.

Our findings from the three studies can be summarized in three main points. First, when planning to distribute a joint task, people rely more on strategies that impose a temporal order rather than strategies that use a featural one. The choice of exactly which strategy to use, however, is likely dependent on which requires the overall least mental effort to execute. Second, when achieving distributive fairness between partners is difficult, pairs tend to rely on a fair procedure to distribute the task between partners instead. This is even if use of the fair procedure does not lead to a fair distribution of effort between partners. Lastly, results from these three studies demonstrate that the two new methods of measuring planning time and the use of the imaginary joint condition are effective and fruitful at investigating the cognitive processes involved in planning a fair task distribution.

The first key finding from this thesis is that between the featural and temporal approaches to planning a fair task distribution, pairs generally preferred strategies that impose a temporal order. Across the five experiments in the first two studies, we observed pairs frequently using either turn-taking or minimal coordination heuristics. These strategies appear to help pairs minimize the amount of mentalizing needed, so much so that when these heuristics were supported by perceptual features in Study 1 Experiment 2, pairs gained a planning advantage over individuals. One possible reason why pairs prefer to use a temporal order rather than a featural one may be that a common ground (Clark, 1996) is usually needed first before a featural order can be implemented effectively for a task distribution. Pairs would need to be certain what feature of the task each partner will be responding to for coordination to be successful. Two ways by which such common ground can be facilitated include being familiar with your partners (Austin, 2003; Wegner et al., 1991) or having mutual expertise with the task (Noy et al., 2011). However, if the task is new or not well-understood, or if partners are not familiar with each other, then establishing who does what in a joint action might require much more time and repeated interactions between partners. By comparison, a temporal order that specifies only when a partner should respond in a task might be simpler and more expedient, especially if the joint task is new and partners are practically strangers.

Not all strategies that impose a temporal order are used equally, however. Whichever strategy was preferred can depend not only on what constitutes a fair task distribution for the partners, but very much on whichever strategy was easiest to plan for and execute. In Study 1 Experiment 3, when pairs needed to ensure that each partner performed certain types of actions for a certain number of times, minimal coordination was preferred over the turn-taking heuristic. Minimal coordination allowed partners to keep track of the different types of actions needed with fewer interruptions as compared to turn-taking. Turn-taking required many more coordination points, and each coordination point was a potential point where partners could lose track of what action was already performed and what else was needed. In Study 2 on procedural and distributive fairness in task distribution, when items in the task sequence had different effort requirements, turn-taking was preferred over minimal coordination. In this case, minimal coordination required first considering the whole task sequence in order to establish the minimal coordination point. In contrast, no such advanced computation was needed to execute turn-taking; partners simply needed to know who took the last turn to know who goes next.

The second main finding from these studies is on the role of fairness in task distribution planning. From our studies, we find that when achieving distributive fairness in a task distribution gets too difficult, pairs would opt instead to rely on the fairness of a procedure to distribute the task between partners. While most humans are strongly motivated to be fair, this finding shows that how fairness is actually engaged for a task distribution depends on how easy it is to achieve said fairness. This echoes the earlier finding where the choice of strategy that imposes a temporal order depends very much too on whichever was easier to plan for and execute. Would fairness of distribution ever matter then if ease of implementation was the key determiner of how partners plan task distributions? Findings from the third study with the imaginary joint action method clearly shows the contrary. Distributive fairness does matter and can guide how fair procedures are used for joint task distributions.

It remains an open question then, if there exists a common tipping point by which one concept of fairness gives way to the other and if this tipping point is determined by the ease of implementation or by the degree of (un)fairness it engenders. Different conceptions of fairness can clearly exist with different levels of implementation ease and result in conflicting degrees of fairness and inequality. One immediate way to explore this with procedural and distributive fairness would be to use varying degrees of effort asymmetry in a task sequence and to observe at which degree of effort asymmetry procedural fairness is given up for distributive fairness, and vice versa. This approach would not only help reflect the complexity of fairness as we are starting to understand it, but also provide a better picture of how different scales of disparity within a task can motivate the different ways by which a fair task distribution is achieved.

The third main outcome of this thesis consists of the two new methods developed to access the planning process. The first method is the use of a planning time measure as a proxy for how much mentalizing was involved in the planning stage. Across the different experiments in this thesis, planning time was generally a good measure of how difficult it was to plan for a task distribution. Be it whether this difficulty was due to ambiguous stimulus-response mappings (Study 1 Experiment 1), ambiguous perceptual features (Study 1 Experiment 2), action constraints (Study 1 Experiment 3), or effort asymmetry (Study 2), the length of planning time served as a good measure of how much mental effort was required to plan for a fair task distribution. When compared between individuals and pairs specifically, the length of planning time was also a good proxy for how much mentalizing was needed to predict and account for a partner's action in a task distribution. In this case, we find that while pairs mentalized and took a longer planning time than individuals across the different studies, the use of heuristics was able to help minimize the mentalizing effort required. This was particularly striking in Study 1 Experiment 2, where pairs took less planning time than individuals who needed only to plan for a distribution between their two hands.

The findings that pairs did not take a longer planning time than individuals when an effort asymmetry was present in the task (Study 2), and that participants in the imaginary joint did not take a longer planning time the way actual pairs would when compared to individuals in Study 1 Experiment 1 highlight a limitation of the planning time measure. While a good proxy for measuring the amount of mental effort involved and a helpful indicator of what cognitive mechanisms might be involved, planning time measurements alone cannot tell us the exact nature of how the cognitive mechanisms were used. It is possible, for instance, that the similar planning times in Study 2 were driven differently for pairs and individuals. Pairs could have been mentalizing and trying to predict what their partners will do while individuals could have been busy trying to figure out the easiest or most interesting way to complete a repetitive task. As pairs had used heuristics in Study 2, planning time for pairs could also have been shortened such that the time they took was no different to individuals.

Similarly, it is difficult to detail the nature of the cognitive mechanisms involved in Study 3 Experiment 1, where participants in the imaginary joint condition did not take a longer planning time than individuals. While it is possible that mentalizing was less involved when imagining a social interaction as compared to an actual social interaction, it is impossible to tell without more definitive measures of mentalizing. The medial prefrontal cortex, for example, is a key brain area found to be involved in mentalizing (C. D. Frith & Frith, 2006b). In a neuroimaging study by Gallagher and colleagues (2002), increased activation of the anterior paracingulate region, as located within the medial prefrontal cortex, was found when participants believed themselves to be playing 'stone, paper, scissors' against a person than when playing against a computer. This was even if both were technically playing against a computer. Activity in this same brain region was also found in another study where participants thought of observed rather than unobserved agents (Spiers & Maguire, 2006). In this study, licensed taxi drivers were scanned in an MRI scanner as they drove customers to their destinations in a virtual reality game. This virtual reality environment was a simulation of busy London and featured other drivers and pedestrians while the customers who taxi drivers drove about in the game were pre-recorded audio commands and never visible. In both studies, greater activity in the medial prefrontal cortex was driven by increased demand to know and guess what someone would be doing next, be it whether they will be showing ‘paper’ or ‘scissors’ next, or if they will be crossing the road 500m ahead.

Accordingly, it is likely that participants in the actual joint condition have more need to predict and interpret the actions of their partners as compared to participants in the imaginary joint condition. In the actual joint condition, it was important for pairs to figure out what their partners will be doing in order to achieve a fair task distribution. In the imaginary joint condition, however, it was not as necessary to figure out what each friend will do in order to achieve a fair task distribution. Participants imagining how their friends would distribute the task could simply decide for them. Nevertheless, it is difficult to conclude from planning time alone how exactly mentalizing was involved in these specific cases. Future studies could include neuroimaging methods alongside the use of planning time to gain a more insightful picture of the cognitive processes while planning.

The second new method is the use of the imaginary joint action condition. We were not only able to find in the imaginary joint condition the same strategies that were being used in an actual joint task distribution, but to also reveal how exactly people planned to achieve fair task distributions between partners. Specifically, that heuristics were used even in the imaginary joint condition highlights how strongly these strategies appeal to people planning for task distributions in the joint mode, imaginary or not. In Study 3 Experiment 1 especially, one could argue that having full control of how the task distribution is to be performed would make use of a featural order easier. While no actual common ground is achieved between partners, participants in the imaginary joint condition could simply decide which partner will be responding to what colour subtasks, much in the same way participants in the individual task distribution decide which hand will be responding to what colour subtasks. That this was not the case provides strong support that these turn-taking and minimal coordination strategies are indeed dedicated social heuristics and not heuristics of a general nature.

It remains an open question then, if an actual common ground between the partners (imaginary or actual) involved is necessary for the use of perceptual features in a joint task distribution. This can be tested with the same experiment by including an open channel of communication during the planning stage. Partners would be able to explicitly discuss their task distribution plans and establish a common ground much quicker. Given how heuristics have been shown to help pairs minimize mentalizing, however, it would be interesting to see what partners choose when planning their task distributions.

Another finding possible only with the imaginary joint action method was that we got to put together a more informed picture regarding how distributive fairness affects the task distribution process. As results from Study 3 Experiment 2 show, without the potential coordination problems from an actual task distribution, most people were concerned with and wanted to achieve distributive fairness. Importantly, distributive fairness was not neglected for the more easily achievable procedural fairness but rather, influenced how a fair procedure was used in order to achieve distributive fairness. It now remains to be seen under what conditions distributive fairness can similarly facilitate the use of a fair procedure with actual pairs and not lead to a choice of procedural fairness over distributive fairness. Ideas previously discussed such as varying the degree of effort asymmetry in the task and including an open channel of communication while planning are also likely factors to influence how actual pairs use a fair procedure to achieve distributive fairness.

Another experiment that can be run with the imaginary joint action method would be to investigate how social status of partners influence the planning and performing of fair task distributions. For example, people were more likely to accept unfair offers in an Ultimatum game while under a cognitive load and when the proposer was of higher social status (Harris et al., 2020). Interestingly, people who reported high social status were more likely to accept unfair offers in general than people who reported low social status (Harris et al., 2020). Lower status individuals, however, were expected and also more likely to defer to people of higher status in pure coordination games (de Kwaadsteniet & van Dijk, 2010). These results highlight some of the real-world complexity that affects how fairness is carried out and achieved. Factors like social status feature very much in everyday life, can vary depending on the context, and can have real consequence on how fairly we interact with others. The imaginary joint action method would be most helpful in showing first how exactly people expect individuals with different social status to work together on a joint task. From there, we can find out if these expectations match actual task distributions performed by people with real and different social positions, or if achieving fairness is a stronger factor than social status differences at determining how people distribute a joint task together.

In this research project, the designs for the experiments in each study were kept mostly the same throughout. Each experiment featured a task sequence of eight items which would be first previewed, then responded to item by item in the order indicated by the task sequence. While the task sequences used across the various experiments in this thesis were different, they were all, however, of a common design of eight sequential items to be distributed between two partners or two hands. Importantly, because distributions on these task sequences require that only one partner or one hand respond each time, this suggests that a temporal order might already be inherent in the design of the task. Accordingly, it is not impossible that this task design might have biased participants into preferring strategies that impose a temporal order over a featural one. It should be noted though, that even with this possible bias, there was a clear difference between individual and joint task distributions that cannot be entirely due to the design of the task. Specifically, in Study 3 Experiment 2 where participants in the imaginary joint condition could distribute the task in the featural order the same way participants in the individual condition did (especially since they were all technically doing the same task distribution for two hands), they chose instead to opt for strategies that impose a temporal order. It is thus more likely that this preference for a temporal order in task distribution is due to the joint mode rather than the design of the task.

Regardless, it would be prudent to investigate if the cognitive processes involved in task distribution for a task sequence would be the same for tasks of a different design. As with a task involving partners tracking multiple objects, merely changing the orientation of the task display was enough to influence the preference of a task distribution strategy (Wahn & Kingstone, 2020). In this case, while a top-bottom division of labour was preferred by pairs tracking multiple objects on a portrait task display, this preference was much reduced when a landscape task display was used instead. Then, there are tasks for which a temporal order may not be as efficient as a featural order for task distribution. These are often tasks where partners can work in tandem with each other, like with assembling a toy model, for example (Raveendran et al., 2016). It would also be an interesting and important question to examine how fairness influences the distribution of such tasks between partners.

Task distribution between partners is a phenomenon common in everyday life. From the domestic setting to the work setting, and even to the policy level, how people plan to distribute a task and distribute it fairly is an important question that has not been asked very frequently from a Cognitive Science perspective. Further studies addressing this important question can make a significant contribution to our understanding of the cognitive bases supporting social interaction.

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ACKNOWLEDGEMENT

TO EXTERNAL FUNDING AGENCIES

CONTRIBUTING TO PHD DISSERTATIONS

Name of doctoral candidate: Jennifer Ang

Title of dissertation: Planning for a Joint Task Distribution: To be Fair and Timely

Name of supervisor(s): Günther Knoblich and Natalie Sebanz

External funding agency: **European Research Council**

Acknowledgement:

This research has received funding from the European Research Council (ERC) under the European Union's Seventh Framework Programme (FP7/2007-2013) under **grant agreement No. 609819 – SOMICS.**