Cognitive distance and group performance

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COGNITIVE DISTANCE AND GROUP PERFORMANCE

PROEFSCHRIFT

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	Dr. L.L.Greer

to Radu & Nicoleta Zara,

whose warmth & inner beauty

I will always keep close to my heart

Contents

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Chapter 1

COGNITIVE DISTANCE AND GROUP PERFORMANCE: AN INTRODUCTION

1.1. Setting the stage

Groups as information-processing systems, are constantly involved in decoding and translating data into meaningful knowledge to be further integrated into collective outputs (Hinsz, Tindale & Vollrath, 1997). This conceptualization fits well into the realm of organizations, in which groups are more and more required to perform complex cognitive tasks (Devine, 2002; Dahlin & Weingart & Hinds, 2005). Group's success in satisfying organizational requirements depends not only on the ways in which relevant information is being integrated (through group processes) but also on the individual characteristics (e.g. abilities, behavioural patterns) brought by its composing members. The IMOI (input-mediator-output-input) group model (Ilgen et al., 2005) further depicts causal links between inputs, processes/emergent states and group performance. This thesis departs from positioning the current work into this particular model of group functioning, in which groups as information-processing systems transform and translate resource inputs into meaningful outputs aimed to satisfy various organizational demands. In doing so we contribute not only to the input part (while investigating the impact of various individual distance configurations upon group performance) but also to the process part (while investigating the impact of several group processes on group performance). Furthermore, our research attempts do not stop at the level of explaining why some groups perform better than others. Groups are employed in organizations with the assumption that they should be able to perform better than standalone individuals. Consequently, we also look at performance, in terms of synergy, or group's ability to perform better than the average group members (weak cognitive synergy) or its best performing group member (strong cognitive synergy).

Within the IMOI framework, the current thesis aims to bring several contributions to groups as complex cognitive systems. First, we come to challenge the linearity assumption according to which group performance linearly grows as a function of input or process variables. Given that groups are complex cognitive systems we argue that the nature of the relationships among group variables also unfolds in a rather complex way, oftentimes in a non-linear fashion (Anderson, 1999). We address this issue in two empirical studies in which we investigate how the level (high, moderate, and low) of distinct characteristics of group members (e.g. abilities) or processes (e.g. minority dissent) impacts differentially on group's performance. Secondly, we contribute to the understanding of group cognitive processes, prone to influence group performance. Group cognition, as the way in which knowledge is organized and distributed within the group (Kozlowski & Ilgen, 2006) has received considerable attention in the group research. A recent meta-analysis indicates the importance of group cognition not only to group performance but also to group behavioural processes and motivational states (DeChurch & Mesmer-Magnus, 2010). However, the cognitive processes through which information is being processed/integrated within groups has received considerably little attention (Huber & Lewis, 2010; Weingart, Todorova & Cronin, 2008). We contribute to this particular line of research by proposing and investigating integrating mechanism (e.g. link activation) and decision rules and their link with group performance.

1.2. Lost in translation: distance configurations in groups

> *"F1: Yes, I don't want to argue, and I want to explain to you that I'm not going to push my ideas. My idea is not to push my ideas, I'm trying to…it might be cause we are from different places, and from different areas you know, you're a*

design student, I'm a business student, we do really differ. We think differently. So it might seem to you that I would push my idea, but no, I'm trying to explain it to you, cause I'm that sort of a person, I have to see everything clearly, for…in order for me to act…and make the plan….If I cannot see it clearly, I cannot put the values to here and here, and I cannot combine them, I cannot make the plan. So do you….

M1: You know why we have this conflict? It is because when you explain these things, you explain it very well, but I don't understand…

F1: yeah, and that's why I keep on explaining, cause I know I can see that you might not understand, so I keep on explaining, trying to think of another way to explain, but the others, they might seem that you're pushing it, you're pushing it, but actually I'm not, I'm just trying to explain it to you…

M1: make us understand…

F1: yeah, so I just hope you understand it…."

(Day 8 of a group working on developing a business model for a Finnish company)

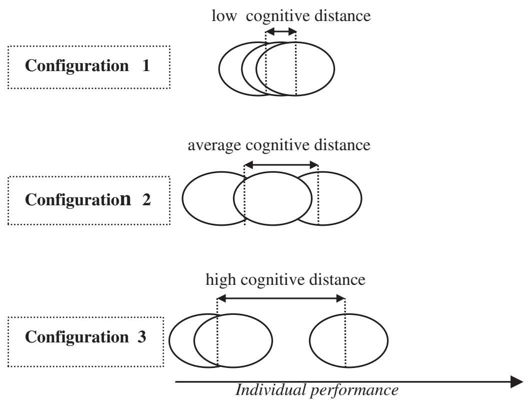
This example illustrates a group situation in which distance in knowledge and expertise among the group members brings with it understanding barriers difficult to surpass. Group members are lost into their attempts of translating their ideas to each other. As reported at the end of the day, the atmosphere in the group was tensed and upset with little progress being made for the project. The natural question arising here is how much distance between the group members (e.g. in abilities, or behavioural styles) is in fact allowable for the group to perform well?

The term of cognitive distance has been first coined in the inter-organizational literature, being broadly defined as the differences in ways in which people perceive, interpret, understand and evaluate the environment (Nooteboom, 2000). Cognitive distance has been shown to have an inverted U shape relationship with learning and innovation (Nooteboom, 2000). If cognitive distance is too low, there is not enough novelty companies involved in collaboration can benefit from, while if the cognitive distance is too high, the companies are not able to communicate effectively and cannot find a common ground conducive for learning and innovation (Nooteboom et al., 2007).

We are extending the concept of cognitive distance to groups following a group configurational approach (Klein & Kozlowski, 2000) to explore group performance under several distance configurations. Configural group properties originate from individual group members' cognitions or behaviours, however the focus does not fall on these individual characteristics per se but rather on how these characteristics are configured within a group and how these configurations further impact group performance.

The first type of configuration we are investigating is distance in abilities/performance. We define cognitive distance in this particular type of configuration as the detachment (in terms of accuracy and completeness of individual initial task judgments) of the best performing individual from the rest of the group. Figure 1.1. depicts three possible group configurations in abilities.

Figure 1.1. *Configurations of (ability) cognitive distance in groups*



The first configuration illustrates the situation in which all group members scores for the task are extremely close to each other (low cognitive distance), the second configuration indicates the case in which the best performing individual is rather detached from the rest of the group (medium cognitive distance) while the last configuration illustrates a case in which one group member score is highly detached from the rest of the scores (high cognitive distance). In the inter-organizational field, the second configuration, in which there is an average cognitive distance among companies involved in collaboration, has been found to be the most conducive to performance and innovation (Nooteboom, 2000). While trying to replicate these findings at a group level we are striving to answer the following research question:

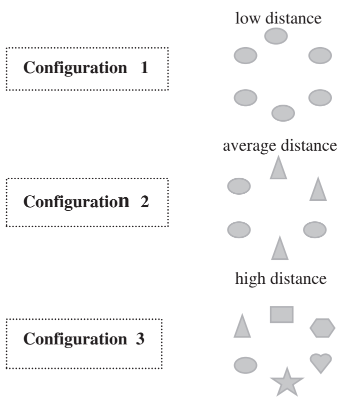
RQ1 To what extent do distinct cognitive distance configurations differentiate group performance?

Groups are employed in organizations with the assumption that they should produce outcomes which are superior to the ones produced by standalone group members. Therefore, next to knowing which distance configuration is the most conducive to group performance we are also interested in exploring whether groups as collectives manage to become better than the average individuals in the group (weak cognitive synergy) or the best performing group member (strong cognitive synergy) in specific cognitive distance configurations. This comes to bring contributions to the group cognitive synergy stream of research, where little attention has been devoted to the direct effect of various group configurations (with respect to individual cognitive abilities). Thus, the second research question of the dissertation is:

RQ2 Do groups manage to reach weak and strong cognitive synergy in specific cognitive distance configurations?

The second type of configuration we are exploring is distance in behavioural patterns (roles). Apart from their functional role group members have the tendency to display particular behavioural patterns which are rooted in generic personality traits and individual differences. Belbin (1981) identifies nine such possible roles and the major assumption advanced is that groups in which all the roles are represented at a high or very high level should reach the highest level of performance. In other words, high distance among group members' roles is the configuration in which groups perform the best (configuration 3 in Figure 1.2.). In the third configuration group members possess unique behavioural patterns that according to Belbin balance well one with another and create synergetic patterns of interaction. When group members detain the same unique role (first configuration), groups will develop a pattern on its own which will detriment group's performance. For instance, a group of only resource investigators will be mainly oriented towards exploring information available in the group without focusing on other parts of the teamwork, such as coordination or assuring that the project is being delivered in time, given that relevant roles for these components are missing.

Figure 1.2. *Configurations of (role) cognitive distance in groups*



Belbin's claims with respect to role configurations have been extensively used in organizations although they have created lots of scientific controversy too (Belbin, 1993; Furnham, Steele & Pendleton, 1993), with empirical results failing to fully support the advanced assumption that groups attain the highest level of performance when the roles detained by its members are unique and different one from each other (Senior, 1997; Partignton & Harris, 1999; Water, Ahaus & Rozier, 2008; Jackson, 2002; Blenkinsop & Maddison, 2006). While using a comprehensive approach to groups, in which we analyse the impact of several roles configurations upon several group performance indicators across time we are trying to shed some light on this issue and therefore answer the following research question:

RQ3 Is group role balance (distance) a relevant dimension for predicting group performance?

While trying to answer these first three research questions we bring several theoretical contributions. At a broader level, we contribute to the input part of the IMOI model (Ilgen et al., 2005) and literature on configural group by indicating which initial group configurations in terms of abilities or behavioural patterns are the most conducive to group performance and group cognitive synergy. In particular, we bring several contributions to the cognitive distance conceptualization: 1) theoretically by extending the concept to a group level and developing an overarching model which explains how different configurations contribute to group performance 2) by exploring alternative ways in which cognitive distance is measured and operationalized, and 3)we also contribute to the cognitive synergy stream of research, by investigating the direct effect of various group distance configurations.

1.3. Analogy-making as a group knowledge translation tool

> *"Archimedes (3rd century B.C.) has been asked to determine whether base metal has been substituted for gold in an intricately designed crown ordered by his king. Although the weight per volume of pure gold was known, the crown was so ornate that its volume was impossible to measure. Archimedes was unable to see a solution to this problem until he went home and stepped into the bath. He then saw an analogy between the volume of water displayed by his body as he got into his bath, and the volume of water that would be displaced by the crown. The problem was solved. By immersing the crown in water, he could work out whether it was made of pure gold"*
>
> *(Goswami, 1992, p. 1)*

Analogy-making theories play an important role in the cognitive science field. At the core of analogy-making lies the ability to find a structural alignment or mapping between knowledge domains. In particular, analogy-making can be defined as the importation of knowledge from a familiar source onto a less well-known target by the establishment of correspondences between the two (Spellman & Holyoak, 1996; Blanchette & Dunbar, 2001). The structure-mapping theory of analogy has received considerably empirical evidence (Markman & Gentner, 1993; Clement & Gentner, 1991) and the diverse manifestations of analogy (in facilitating understanding, learning and reasoning) bring support to the claim that analogy-making is a critical part of the core of cognition (Holyoak & Gentner, 2001). For instance, teaching by examples and drawing comparisons across examples via analogy facilitates understanding and learning in educational environments (Gentner, Loewenstein & Thompson, 2003; Kurtz, Miao & Gentner, 2001). Analogies are efficient in communicating emphatic understanding in clinical psychology settings (Kaufmann & Miller, 1977) and are widely used in argumentative political discourses (Blanchette & Dunbar, 2001) in problem-solving tasks (Gick, Holyoak, 1980; Kurtz & Loewenstein, 2007) and creativity processes (Christensen & Schunn, 2005).

Although analogy-making proves to be a useful tool in a large array of social contexts, the number of studies investigating how analogies work in groups and their functions are rather few. Studies coming from cognitive science analyze the role of analogies in scientific groups (Dunbar, 1995; Dunbar & Blanchette, 2001) and groups involved in creative processes (Christensen & Schunn, 2007; Dahl & Moreau, 2002). Analogies have been found to play an important role in identifying and explaining new concepts (Christensen & Schunn, 2007), solve problems or conceptual change (Dunbar, 1995).

However, in these studies analogies are rather analyzed from a cognitive perspective, groups representing only the context in which this cognitive process can be studied in a realistic setting.

We bring these analogy-making insights from cognitive science into the realm of group dynamics, in an attempt to shed more light on the functioning of group processes, thus contribute to the mediator part of the IMOI model (Ilgen et al., 2005). In doing this, we develop at least two usages of analogy-making theories in groups.

The first extension of analogy-making to groups is as a cognitive bridging mechanism. As described in the previous section, group members often find themselves in various distance configurations with respect to their level of abilities, knowledge or behavioral patterns of interaction. Given that distance is associated with difficulties in knowledge bridging and understanding, a natural question emerging is how groups manage to reduce the knowledge distance in such a way that group performance is being preserved. Concepts such as cross-understanding and cognitive integration have been advanced as possible processes that should facilitate understanding & knowledge bridging. Cross-understanding reflects the extent to which group members have an accurate understanding of one another's mental models with respect to what others know, believe or are sensitive to (Huber & Lewis, 2010). The concept comes close to cognitive integration which illustrates the ability of group members to understand, anticipate and integrate one another's perspective as a way of reducing representational gaps (Weingart, Todorova & Cronin, 2008). Both concepts describe the same process of cognitive integration or bridging cognitive distance. However, they are approaching the problem in a rather normative manner, arguing that groups should use cross-understanding in order to cognitively integrate the knowledge at hand, without actually explaining how integration or cross-understanding can be attained.

Drawing on analogy-making theories we develop a cognitive bridging mechanism meant to fill in this gap of integrating distant knowledge domains. The link activation mechanism defines the way in which group members find and apply similarities between two different and apparently unrelated knowledge structures. This similarity is identified and used with cognitive bridges such as an analogy/metaphor (Gentner, Bowdle, Wolff & Boronat, 2001). The activation of links between unrelated knowledge areas generates an active information exchange in which components and relations belonging to one domain are being mapped into other unrelated knowledge areas, facilitating understanding and the creation of new knowledge. As in the example presented at the beginning of this subsection, Archimedes experiences a link activation at the moment in which he steps into the water to take a bath. Then, he immediately aligns and transfer knowledge from one area (the volume of water displayed by his body while taking a bath) to a totally unrelated one (measuring the volume of the king's crown), in such a way that he finds a creative solution to his problem of determining whether the crown was made of pure gold (by immersing the crown in the water he could estimate its volume). To model and develop this knowledge bridging mechanism theoretically and empirically, we ask the following research question:

RQ4 To what extent does link activation affect knowledge bridging & group creativity?

The second extension of analogical thinking in groups is as a strategy of learning viable decision-making heuristics which are meant to bring the group decisions at levels that outperform not only the expertise of the average group members (weak cognitive synergy) but also the best individual in the group (strong cognitive synergy). Although groups have the potential to become superior (as interacting collectives) to individuals alone or simple aggregation of individual actions or competencies, this (emergent) potential is not always realized in real-life situations. Studies coming from the group synergy literature illustrate not only that groups do not perform better than their best individual member (Bonner, Gonzalez & Sommer, 2004; Fischer, 1981) but sometimes they even perform worse than the average individual performance in the group (Buehler, Messervey & Griffin, 2005; Hinsz, Tindale & Nagao, 2008). One way in which groups can increase the quality of their collective choices in order to outperform their best performing individuals is through specific decision rules (guiding norms for group interaction). Rules such as the collaborative one has been proved to bring an increase to the group's potential of reaching synergy, with groups performing better in the collaborative condition (where opinion sharing and equal participation of all group members is being encouraged) than in the consultative one (where the group members follow the decision of an appointed leader) (Curșeu et al., 2013). Although in the collaborative rule groups perform better than in the consultative one, in absolute terms synergy is still not being achieved. Thus, an emerging challenge is to find the conditions in which groups manage to attain cognitive synergy.

While drawing on analogy-making theories of structure mapping (Gentner, Holyoak & Kokinov, 2001) we address this challenge by developing a condition (analogical one) under which groups have the potential of learning group decision-making rules (e.g. identify-the-best, collaborative) which should bring them at real levels of cognitive synergy. The analogical condition relies on a simple adaptive decision-making heuristic (imitate-the-successful) which does not require groups to draw on a large pool of information when establishing their group strategy and deciding but rather on little amounts of information with the purpose of making faster, frugal and accurate decisions (Gigerenzer & Gaissmaier, 2011, Toelch et al., 2009, 2010). Therefore, our last research question is:

RQ5 To what extent does the way in which decision rules are induced (analogical vs. direct) influence group's ability to reach absolute levels of weak and cognitive synergy?

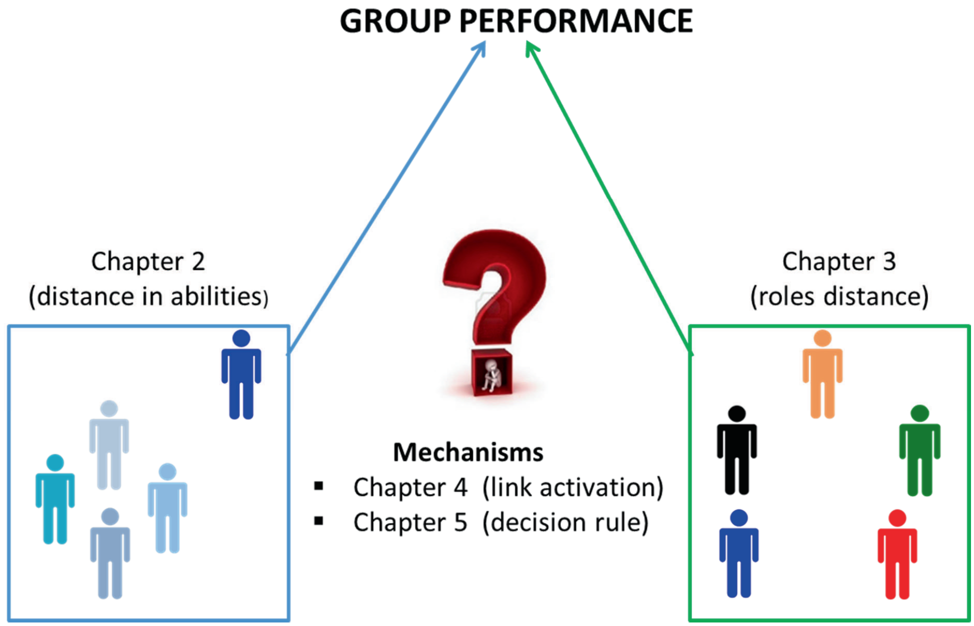
While trying to answer these last two research questions we bring several theoretical contributions. At a broader level, we contribute to the mediator part of the IMOI model (Ilgen et al., 2005) by trying to better understand the role of processes such as link activation and decision rules for group performance and group cognitive synergy. In doing this, we contribute to the group dynamics stream of research by bringing insights from cognitive science, especially the analogy-making part. At a micro level, we contribute to the theories of representational gaps and cross-understanding by proposing more detailed cognitive mechanisms through which knowledge bridging can be achieved (Weingart, Todorova & Cronin, 2008; Huber & Lewis, 2010). We also contribute to the cognitive synergy and decision-making stream of research by proposing new guiding norms for group interaction and new ways of rule inducements, such as the analogical type of inducement.

1.4. Structure of the dissertation

In order to address the advanced research questions, the current dissertation is structured as follows: the second and the third chapter approach cognitive distance in terms of configurations (distance in abilities and role distance) and their impact upon group performance and group cognitive synergy. The fourth and the fifth chapter approach the process part (link activation and decision rules) and their impact upon group creativity and group cognitive synergy. See also Figure 1.3.

In **chapter two** we address the first type of distance configuration (distance in abilities) and its impact upon group performance and group cognitive synergy. We hypothesize that the relationship between cognitive distance and group cognitive synergy has an inverted U shape and we test this curvilinear relationship in two studies using judgmental and decision making tasks. The first study shows that cognitive distance is beneficial for both weak and strong group cognitive synergy up to a point and then it becomes detrimental. A second study replicates the findings only for weak and not for strong synergy in a task that evaluates individual and collective rationality (as an emergent group level cognitive competence) in decision making.

Figure 1.3. *Dissertation structure*



Chapter three addresses the second type of distance configuration, distance in behavioral patterns. In a sample of 84 student groups this multi-method longitudinal study tests the impact of group role balance (distance) upon teamwork quality and three performance indicators in collaborative learning groups (group cognitive complexity, perceived performance and actual performance). The results show that group role balance (where there is a maximum distance between the roles) positively predicts group cognitive complexity but only when balance is seen as a configural property of groups instead of a sum of individual roles. Group role balance does not predict however any of the other performance indicators, bringing thus little support for Belbin's initial claims. While the second and the third chapter are focused on investigating the impact of distance configurations (in abilities and behavioral patterns) upon group performance and group cognitive synergy, the fourth and the fifth chapter focuses on group processes.

In the **fourth chapter** we explore link activation and minority dissent as two mechanisms through which teamwork creativity is enhanced. We initially expected that groups in a condition of link activation between two different knowledge structures (as an experimental manipulation) will be more creative in their teamwork than groups without activation. Our results indicate that groups become indeed more creative but only when a cognitive process such as link activation is being sustained by a more social process such as minority dissent.

Finally, our **fifth chapter** explores the superiority of the analogically induced decision rules as opposed to the directly induced rules for group cognitive synergy. In a first decision-making experimental study, groups have been instructed to follow either a collaboration or a heuristic rule (follow-the-best) which were induced either in a direct or an analogical way. Our results indicate the superiority of the analogically induced rules. The results have been further replicated in a second study.

Table 1. *Overview of the chapters in which research questions are addressed*

RESEARCH QUESTION	CHAPTER(S)
RQ1 To what extent do distinct cognitive distance configurations differentiate group performance?	2, 3
RQ2 Do groups manage to reach weak and strong cognitive synergy in specific cognitive distance configurations?	2
RQ3 Is group role balance (distance) a relevant dimension for predicting group performance?	3
RQ4 To what extent does link activation affect knowledge bridging & group creativity?	4
RQ5 To what extent does the way in which decision rules are induced (analogical vs. direct) influence group's ability to reach absolute levels of weak and cognitive synergy?	5

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Chapter 2

TOO CLOSE OR TOO FAR HURTS: COGNITIVE DISTANCE AND GROUP COGNITIVE SYNERGY[1]

2.1. Introduction

Organizational groups perform a variety of cognitive tasks ranging from research and development to strategic decision making (Devine, 2002; Dahlin & Weingart & Hinds, 2005). Therefore organizational success depends on groups' abilities to effectively process information and solve highly complex problems (DeChurch & Mesmer-Magnus, 2010; Straus, Parker & Bruce, 2011). As groups are information processing systems (Hinsz, Tindale & Vollrath, 1997; Woolley, Chabris, Pentland, Hashmi & Malone, 2010), understanding how the cognitive performance of individual group members builds into collective cognitive performance in small group settings becomes increasingly important. Research on cognitive diversity illustrates how group performance is influenced by group members' cognitive characteristics such as information-processing styles, cognitive schemas and abilities (Miller, Burke & Glick, 1998; Kilduff, Angelmar & Mehra, 2000; Volkema & Gorman, 1998). Diversity in cognitive abilities in particular illustrates the extent to which group members differ in terms of their capabilities to contribute to a cognitive task. Given that the level of cognitive ability has been assessed as one of the best predictors of individual job performance (Devine & Philips, 2001) a range of studies have been devoted to investigate the impact of minimum, maximum and average individual cognitive ability on group performance (Williams & Sternberg, 1988; Barrick et al. 1998). Collective performance requires a balance between cognitive differences and similarities in groups or in other words an "optimum" level of cognitive diversity. Building on this insight

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and using a configural approach to groups (Klein & Kozlowski, 2000) we argue that exploring group performance under various configurations of individual cognitive abilities (in particular cognitive distance) can further extend our understanding of the complex relationship between group diversity and performance.

The group synergy and group diversity are two separate streams of research. The cognitive synergy literature uses various cognitive tasks to directly address differences in individual performance. As such, it offers several valuable insights on how the performance of individual group members influences collective performance and thus can complement research on group diversity. Group synergy reflects the objective gain in performance as compared to the average individual performance (weak synergy) or the performance of the best performing group member (strong synergy) that is attributable to group interaction (Larson, 2010). In the context of group synergy, variance in individual cognitive performance (in judgmental, decision-making or problem tasks) becomes much more salient than group heterogeneity in other personal attributes (Henry, 1993). Although in the group synergy literature various studies have related interpersonal interactions to the emergence of group synergy, we are not aware of studies that considered the impact of configural group properties, in particular cognitive distance on group synergy. We define cognitive distance here as a group property that describes the detachment (in accuracy and completeness of judgments) of the best performing individual from the rest of the group. Moreover, in the meta-analysis of Devine and Philips (2001), the authors pointed out that within group variance in cognitive abilities yields inconsistent results on group performance and in terms of configural group properties, studies mostly focused on the highest/lowest score as well as on the average and variance within group with no account of cognitive distance.

An underlying element of the tasks used in the group synergy literature is that the collective task (being judgmental or decision making) can, in theory, be accomplished by each individual group member alone (disjunctive tasks, see

Steiner, 1972). In such tasks, the contributions of the best performing individual in the group are especially important as he/she alone can successfully accomplish the group task (Steiner, 1972). However these tasks have collaborative elements too, as all group members are asked to share their insights and contribute to the task. In this context, the "cognitive distance" between the best performing individual and the rest of the group is a key element of groups' potential for achieving cognitive synergy. In particular we argue that average cognitive distance yields the highest potential for achieving synergy, while too little or too high distance reduces the potential for achieving synergy.

Cognitive distance has been first coined in inter-organizational network literature and broadly defined as the differences in ways in which people perceive, interpret, understand and evaluate the environment and shown to have an inverted U shape relationship with learning and innovation (Nooteboom, 2000). If cognitive distance is too low, there is not enough novelty companies involved in collaboration can benefit from, while if the cognitive distance is too high, the companies are not able to communicate effectively and cannot find a common ground conducive for learning and innovation (Nooteboom, Van Haverbeke, Duysters, Gilsing & van den Oord, 2007). We extend these insights to small groups and following the same line of reasoning we advance the idea that the three configurations of cognitive distance described above have a differential impact upon group cognitive synergy. Therefore, the current study aims to contribute to the small group literature in three ways. First, by investigating the distance in abilities between the best performing and the rest of the group members we provide a meaningful insight into the important but understudied concept of cognitive diversity in groups. Second, our study contributes to the group synergy literature, by identifying how cognitive distance affects group synergy. In particular we are exploring the functional form (inverted U shape) of the underlying relationship between cognitive distance and group cognitive synergy. Finally, we are theoretically integrating existing research on cognitive diversity and cognitive synergy in order to develop a comprehensive theoretical framework that explains the impact of group cognitive composition on group synergy.

2.2. Cognitive distance and group cognitive synergy

Group synergy is achieved when the collective performance of interacting individuals exceeds the performance achieved by simple, preprogrammed combination of standalone group member efforts (Larson, 2007). In line with Larson (2007, 2010) we further differentiate between strong and weak cognitive synergy. Groups achieve weak cognitive synergy when collective cognitive performance is better than the average performance of group members and strong cognitive synergy, when collective performance exceeds the performance of the best performing individual in the group (Larson, 2007, p. 415).

Although groups are potentially able to reach weak and even strong synergy, they often struggle to become better than their best individual member or the average performance of the group members. Empirical studies investigating group synergy in judgmental tasks (performing tasks with hard to demonstrate correct answers) indicate that groups are able to reach weak (Henry, 1993; Crede & Sniezek, 2003; Laughlin, Gonzalez, and Sommer, 2003; Sniezek, 1989; Rohrbaugh, 1979) and sometimes strong synergy (Henry, 1993; Crede & Sniezek, 2003; Reagan-Cirinciore, 1994). However, some other research reports found no support for synergy (Bonner, Gonzalez & Sommer, 2004; Fischer, 1981; Gigone&Hastie, 1993, 1996, 1997, Sniezek, 1990) and even more, showed that groups often perform worse than their average individuals (Buehler, Messervey & Griffin, 2005; Hinsz, Tindale & Nagao, 2008; Argote, Devadas, & Melone, 1990).

The potential factors associated to group's success in reaching synergy are diverse. Factors such as prescribed conditions for group interactions (e.g. techniques such as group consensus or social judgment analysis), group communication channel (face vs. video-conferencing) or accentuation of particular biases have been found to influence group's ability to reach synergy

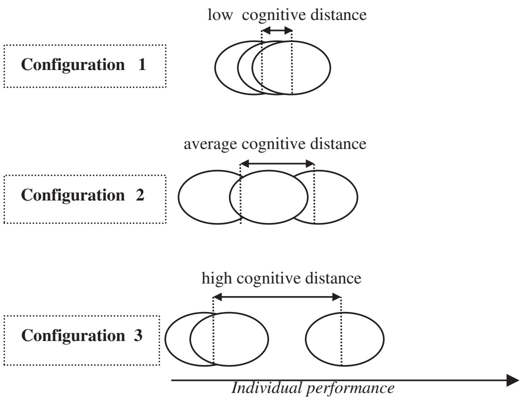
(Reagon-Cirinciore,1994; Sniezek, 1989; Henry, 1993; Rohrbaugh, 1979 ; Crede & Sniezek, 2003; Sniezek,1990; Buehler, Messervey & Griffin, 2005; Hinsz, Tindale & Nagao, 2008; Argote, Devadas, & Melone, 1990).

Although, in terms of processes we have considerable empirical evidence showing the relevance of information sharing, information integration mechanisms, conflict and coordination processes for achieving synergy (Devine & Philips, 2001), so far little effort has been devoted in the group synergy literature to test the direct effects of various group configurations (with respect to individual cognitive performance) on the emergence of group cognitive synergy. Based on meta-analytical evidence, Devine and Philips (2001) proposed an integrative model in which group members' individual cognitive performances impact on group synergy both directly and indirectly (by affecting group processes). Therefore, aggregated individual performance could be used to directly predict group performance, or the extent to which groups achieve synergy.

The way in which group members differ in terms of their cognitive abilities is particularly relevant for the achievement of group cognitive synergy in disjunctive tasks. Disjunctive tasks are types of tasks in which the best individual can successfully perform the group task (Steiner, 1972). In this particular type of tasks, groups should (in principle) at least be able to reach weak cognitive synergy given that group's decision will be at least that of its best individual member. However, different configurations of individual abilities in general and the detachment of the best performing group member from the rest in particular can influence the way in which individual performances are aggregated into collective performance. For instance, little cognitive variation within groups is not conducive for cognitive synergy as individual contributions to the task are likely to be redundant. Nevertheless, a high performing group member does not necessarily guarantee an improvement in group performance as the high performer might be marginalized by the underperforming majority and his/her contributions to the task disregarded. Consequently, during group interactions, the other group members can improve, deteriorate or disregard best member's contributions to the task, as groups have the tendency to discuss mostly shared than unshared information (Gigone & Hastie, 1993; 1997) and to marginalize opinions that differ from the ones of the majority (Curșeu, Schruijer & Boroș, 2012). The best performing group member might also experience a motivational loss triggered by the ability discrepancy perceived in the group (Messe et al., 2002) and reduce his/her task involvement.

We argue therefore that the distance between the best performing individual and the rest of the group is a particularly meaningful antecedent of group cognitive synergy. We use a compositional view on cognitive competencies (DeChurch & Mesmer-Magnus, 2010) and we define cognitive distance as a configural group property that describes the detachment (in terms of accuracy and completeness of individual initial task judgments) of the best performing individual from the rest of the group. We illustrate this definition with an example of a group of individuals asked to make judgments for a series of tasks. As judgmental tasks have usually a correct answer individual performance for such tasks is captured by a range of values describing deviations from the correct performance. Figure 2.1. depicts three group configurations using our conceptualization of cognitive distance in such a task. The first configuration illustrates the situation in which all group members scores for the task are extremely close to each other (low cognitive distance), the second configuration indicates the case in which the best performing individual is rather detached from the rest of the group (medium cognitive distance) while the last configuration illustrates a case in which one group score is highly detached from the rest of the scores (high cognitive distance). Each of these configurations represents the range of individual performance in a given set of tasks. We follow the same argument of overlapping knowledge structures as Sargis and Larson (2002) to argue that the third configuration in Figure 2.1. displays the largest cognitive distance in a judgmental task.

Figure 2.1. *Configurations of cognitive distance in groups*



When cognitive distance is low, group members' scores are situated at the same pole of individual performance. Given the similarity of individual scores, group members will perceive their contribution as being redundant or dispensable and this will further decrease group's member's motivation to get involved in the task and increase free-riding behaviours (Kerr & Bruun, 1983). Another consequence of score similarity is that group members are much more prone to reach early consensus in decision-making without a thorough evaluation of viable alternatives (Janis, 1982). Factors such as decreased motivation, free-riding behaviours and early consensus are likely to block the emergence of strong and weak cognitive synergy. Next to this, the lack of differentiation between individual abilities involves that groups do not have one particularly competent member in the group which could potentially guide group's performance beyond the average of the rest of the group members. Thus we expect that in low cognitive distance configurations both weak and strong cognitive synergy are less likely to be achieved.

When cognitive distance is high (one member scores are much higher than the rest of the group) hypothetically the best individual in the group could help the group to achieve weak and even strong synergy. If the group is to correctly identify and follow the best competent member's solution then at least as a collective it should be able to reach weak cognitive synergy. However, processes pertaining to individuals and group dynamics can disrupt the extent to which groups successfully use the competencies of their members. At an individual level, the most competent member might not be motivated to participate to the task given the discrepancy in abilities within the group. The collective effort model (Karau & Williams, 1993) suggests that individuals will only be willing to work hard on a collective task to the degree in which they expect their efforts to be useful. If the distance in ability is too high the most competent member might find it difficult to bridge his own knowledge with the rest of the group members' and therefore experience a motivational decrease and withdrawal from the group discussions. A similar motivational drop associated with competence discrepancy can be inferred from the Kohler discrepancy effect. When the least competent member identifies a high ability discrepancy between his/her own ability and the rest of the group, he/she will experience a motivational drop and as a consequence engage less with the group task (Messe et al., 2002). At a group level, on the other hand, the information sampling literature extensively shows that, common information has more influence on group discussions and ultimately group decisions than unique information (held by only one group member) (Gigone & Hastie, 1993; 1997). If the best competent member is not motivated to participate to the task and the other group members focus only on their own range of solutions then the group solution will approximate the average group members' solutions, with no performance gain that could lead the group to weak or strong cognitive synergy.

Moderate levels of cognitive distance, are associated with some degree of variability in group member's cognitive abilities and performance. Given the variability, group members are motivated to engage with the task given that they perceive their contributions as being unique and non-redundant. The Kohler discrepancy effect also indicates that group members have the highest motivation to contribute to the task when they perceive moderate levels of discrepancy between their own ability and the other teammates' abilities (Messe et al., 2002). At a group level, variety in distribution of individual judgments triggers information-based social influence due to a need of group members to defend their judgements. The more variety identified in the distribution of individual judgments, the more group performance exceeded average individual performance (Henry, 1993; Sniezek & Henry, 1989). This can also be explained through the fact that variety in judgments triggers task conflict and this type of conflict has been positively associated to performance (Pelled, Eisenhardt & Xin, 1999). The active exchange of information combined with group members' motivation to get involved in the task creates the necessary conditions for the group to achieve cognitive synergy. Thus, we expect that moderate levels of cognitive distance are the most conducive for achieving group cognitive synergy. Given the reasoning above, we advance the following hypothesis:

H1. In a judgmental task cognitive distance has an inverted-U shaped relationship with both strong and weak cognitive synergy.

2.3. Method Study 1

2.3.1. Sample and procedure

The sample consisted of seven hundred and forty students (44.4% women, M_{AGE}= 19, SD=1.35) organized in 159 groups, having 3 to 7 members. The groups had to work together throughout the semester in order to deliver a group project for an organizational studies course. Data was collected in five successive academic years. In an interactive lecture on individuals in groups, students have been instructed to perform the NASA Moon Survival problem first individually and then in groups. The task consists in ranking 15 objects, from the most to the least important for the survival of a space crew that has just crash-landed on the moon (Hall & Watson, 1970). First, group members were instructed to rank the objects individually (10 minutes) and then in groups (15 minutes). All groups received the same amount of time and were instructed to employ the method of group consensus as it has been described in Hall and Watson (1970). This involves that ranking for each of the 15 survival items must be agreed upon by each group member before it becomes a part of the group decision. Moreover, in order to prevent inter-group influences, researchers made sure that students interacted only within groups and no cross talking occurred between groups. The task was performed during a regular workshop, being a part of students' participative learning experiences. At the end of the exercise, students were asked to reflect on how their individual performances influenced (are combined into) collective performance and received feedback regarding the interplay between individual and group decision-making, a topic that was part of their course curriculum.

2.3.2. Measures

Individual and group performance. Individual and group rankings have been compared with the expert rankings reported in Hall and Watson (1970) and the absolute differences (for the paired comparisons) were summed to obtain a performance indicator. Because the summed score reflects how far the individual or group judgments are from the expert rankings (with a high score indicating a low performance and a low score indicating a high performance), the summed score was reversed such that high scores became indicative for high performance on the task and low values became indicative for low performance on the task. The reversed scores (both individual and group) were used for further analyses. Two scores have been computed for group cognitive synergy. Weak cognitive synergy has been computed as the difference between the group (collective) performance and the mean of individual scores (individual performance) in the group while strong cognitive synergy has been computed as the difference between group (collective) performance and the score of the best performing member in the group (Larson, 2007, p. 415). Therefore, the value ranges for weak synergy illustrate the extent to which collective performance deviates from average individual performance while value ranges for strong synergy reflect the extent to which collective performance deviates from the best individual performance in the group. By combining insights on individual and collective performance we are able to compute the cognitive gain attributable to interpersonal interactions in groups.

Cognitive distance. NASA Moon Survival problem is a task with disjunctive components in which the performance of the group is likely to depend on the performance of its best member. Given that one member is (in principle) enough to solve the task, we conceptualize cognitive distance as the relative distance between the highest score in the group and the rest. The distance is best captured by the coefficient of variation (CV), which has been adjusted in this case for group size as suggested in Bedeian and Mossholder (2000): $CV = \frac{\frac{SD}{Mean}}{\sqrt{n-1}}$, where SD is within group standard deviation and n is group size. The adjusted CV is indicative of how 'detached' is the best performing group member from the rest of the group members. The CV has a lower bound of 0 and an upper bound defined by $\sqrt{(n-1)}$ (Martin & Gray, 1971). Given that group size has an impact on the magnitude of CV, and the group sizes in our study vary greatly, this adjustment is needed (Bedeian & Mossholder, 2000). This indicator has been named Cognitive distance 1.

Additional analyses. Because our study included respondents from different study years we have performed an additional data analysis to investigate whether there are systematic differences in synergy across the five years in which we collected the data. Therefore, we have conducted a MANOVA analysis with study year as a factor and weak and strong synergy as dependent variables. For weak synergy $F(4, 154)=2.20$, $p=.07$ while for the strong synergy $F(4, 154)=2.22$, $p=.07$. The results indicate that there are no systematic differences in neither weak nor strong cognitive synergy across different years in which data were collected.

2.3.3. Results

Analyses are based on intact groups (no missing data), as all participants asked to hand in their individual and group results agreed to do so, therefore we had no reason for excluding groups from the analyses (Bieman & Heidemeier, 2012). Means, standard deviations and bivariate correlations are presented in Table 2.1.

Table 2.2. presents the results of a hierarchical OLS regression analysis for weak and strong cognitive synergy. To avoid multicollinearity, we used grand mean centering and in order to account for the within unit covariance of SD and the mean (when using the coefficient of variation in the regression analyses) we followed the advice from Harrison and Klein (2007) and we arranged the OLS regression as follows (ind.perf.=individual performance) [2] :

$$Y = b_0 + b_1(GrSize) + b_2(SD_{ind.perf.}) + b_3\left(\frac{1}{Mean_{ind.perf.}}\right) + b_4 CV_{ind.perf.} + b_5 CV^2{}_{ind.perf.} + c$$

where Y= level of group cognitive synergy, GrSize= Group size, $SD_{ind.perf.}$= standard deviation, CV= coefficient of variation. A significant relation has been found between squared cognitive distance and group cognitive synergy. However, the beta coefficients higher than 1 as well as the VIF value higher than 10 indicate multicolinearity issues (O'Brien, 2007). In order to cross check the validity of the results, we used a heuristic strategy of computing disparity and we calculated an additional score (Cognitive distance2) in which we have subtracted from the score of the best member in the group the average score of the rest of the group members (without the best performer). This is an alternative (heuristic) indicator of how far removed is the best member from the rest of the group and it is inspired from the actor-partner interdependence model (Kenny & Garcia, 2012).

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[2] Groups may also differ on specific diversity attributes such as gender that according to some previous studies (Curşeu, Schruijer & Boroş, 2007; Curşeu, Jansen & Chappin, 2013; Woolley et al., 2010) is indicative of group variety. In order to check the potential influence of gender diversity upon our results we re-ran the analyses while controlling for gender diversity (Teachman's index). As including this control did not alter the pattern of our results, we stick with the most parsimonious model and all analyses are reported without gender diversity.

Table 2.1. *Descriptive statistics and correlations for Study 1*

	Variables	*M*	*SD*	1	2	3	4	5	6	7	8
1.	Group size	4.64	1.38								
2.	1/Mean	.02	0	-.07							
3.	SD individual	10.02	5.45	-.10	-.09						
4.	Cognitive distance1	.16	.10	-.41***	.18**	.86***					
5.	Cognitive distance1^2	.01	.02	-.29**	.02	.46**	.70***				
6.	Cognitive distance2	17.69	10.37	.16**	-.17**	.79***	.60**	.40***			
7.	Cognitive distance2^2	106.91	237.73	-.01	-.13	.47***	.29**	.23**	.63***		
8.	Weak synergy	-4.83	9.31	-.00	.22***	-.07	.03	0	-.19*	-.41***	
9.	Strong synergy	-16.18	11.79	-.04	.19**	-.57***	-.38**	-.20**	-.62**	-.60***	.81**

Note: N=159. *p<.10**<.05***<.01.

A high score is thus indicative of how removed is the best performing member (actor) from the rest of the group (partner). The analyses with this score and the results (Table 2.3.) indicate the same inverted U pattern as the ones using the CV as indicator of group disparity (cognitive distance) for weak cognitive synergy.

Table 2.2. *Results of Regression Analysis of Group Cognitive Synergy on CD*

Step	Independent Variables	Strong Synergy Model 1 β	Strong Synergy Model 2 β	Weak Synergy Model 1 β	Weak Synergy Model 2 β
1	Group size	.05	.18*	.14	.29
	1/Mean	.02	-.09	.12	-.03
	SD Ind	-.96***	-1.35***	-.41*	-.88***
	Cognitive distance1	.47**	1.06***	.43*	1.14***
2	Cognitive distance1^2		-.26**		-.31**
	F-value	23.21***	19.82***	2.94**	3.25***
	F-value change	23.21***	4.26**	2.94**	4.24**
	Adj R^2	.36	.37	.04	.06

Note: for Study 1 *N* = 159; *p<.10.**p<.05.***p<.01; CD= cognitive distance

As shown in Figure 2.2. and 2.3., the inflection point at which group performance starts decreasing is 2.81 for weak cognitive synergy and 13.82 for strong cognitive synergy[3]. Given that for strong cognitive synergy standardized beta coefficients for both cognitive distance and cognitive distance squared are negative and significant (see Model 2 in Table 2.3.) we can conclude that the curvilinear relation between cognitive distance and strong synergy has an increasing negative trend, that is the negative association between cognitive distance and strong cognitive synergy is stronger for high rather than low cognitive distance.

Table2.3. *Results of additional analysis of Group Cognitive Synergy on CD*

Step	Independent Variables	Study 1 Strong Synergy Model 1 β	Study 1 Strong Synergy Model 2 β	Study 1 Weak Synergy Model 1 β	Study 1 Weak Synergy Model 2 β
1	Group size	.06	.02	.02	-.03
	Cognitive distance2	-.64***	-.41***	-.19***	.11
2	Cognitive distance2^2		-.34***		-.48***
	F-value	52.03***	45.88***	3.12**	11.09***
	F-value change	52.03***	20.55***	3.12**	26.02***
	Adj R^2	.39	.46	.02	.16

Note: *N* = 159; *p<.10.**p<.05.***p<.01; CD= cognitive distance

[3] The inflection point has been computed using the unstandardized regression coefficients for cognitive distance (B_1) and cognitive distance quadratic (B_2) in the following formula: $X_{inflection} = -B_1 / 2B_2$ (Weisberg, 2005).

Figure 2.2. *The curvilinear relationship between cognitive distance and weak synergy in Study 1.*

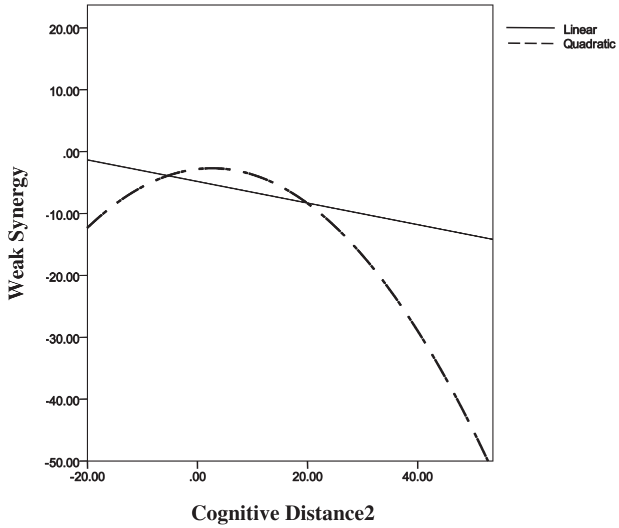
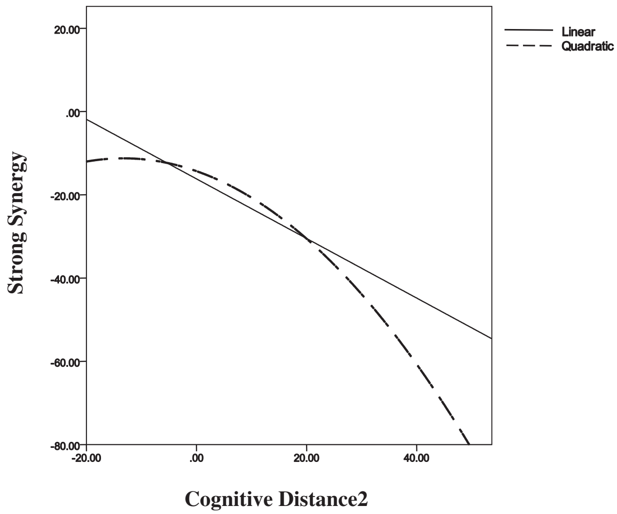


Figure 2.3. *The curvilinear relationship between cognitive distance and strong synergy in Study 1.*



2.4. Discussions Study 1 and introduction Study 2

To conclude, in the first study we used a judgmental task (NASA Moon survival problem, Hall & Watson, 1970) with a hard to demonstrate correct solution. Group members use their task relevant knowledge to demonstrate whether their proposed individual ranking of the items is accurate. If one group member has extensive information regarding moon characteristics she/he can (in principle) help the group achieve a high performance on the collective ranking task. Using this disjunctive task, Study 1 supports the curvilinear association between cognitive distance and group cognitive synergy. In operationalizing cognitive distance we used a content point of view, where reaching the correct solution depends on the accuracy of task-related knowledge.

However, in order to check for the consistency of results across different types of tasks we decided to replicate the study in a decision-making task in which reaching the correct solution depends on rational information processing. We define rationality as the extent to which decisions are aligned with a normative ideal (Shafir & LeBoeuf, 2002). Our approach draws from the heuristics and biases literature and we use a set of decision tasks to explore the extent to which a decision deviates from a normative ideal (e.g., solution which is logically correct) (Curșeu, 2006). Research to date shows that groups tend to accentuate individuals' shared tendencies to be sensitive to biases and heuristics (Tindale, Sheffey & Scott, 1993), yet often group configurations with respect to members' rationality greatly vary. It becomes therefore relevant to understand the way in which group configurations impact on group rationality as an emergent group level competence. If one member is more rational (less sensitive to decision heuristics and biases), then she/he can make the other group members aware of the biases they have and eventually help the group make rational choices. However, if the cognitive distance between the most rational member and the rest of the group is too high, the best performer may encounter difficulties in convincing the other group members. Minority dissent theory indicates that group members who advocate ideas that challenge the position endorsed by a majority tend to be disapproved, rejected and even ostracized (Mucchi-Faina & Pagliaro, 2008; Curşeu, Schruijer & Boros, 2012). The most rational member can also experience a motivational drop given the discrepancy he/she perceives between his/her cognitive ability and the other group members' cognitive abilities (Messe et al., 2002). On the other hand if the cognitive distance is too low and members are similar in their sensitivity to decision-making biases and heuristics, their individual tendencies will be accentuated and the groups will make less rational choices. The second study will further explore the relationship between cognitive distance and group rationality (conceptualized here as strong and weak cognitive synergy) in a set of decision-making tasks adapted from the heuristics and biases literature (Curșeu, 2006) with the following hypothesis:

H2. In a decision-making task, cognitive distance has an inverted-U shaped relationship with group cognitive synergy.

2.5. Method Study 2

2.5.1. Sample and procedure

The sample consisted of five hundred seventy eight students (35.63% women, M_{AGE}= 19, SD=1.54), organized in 132 groups. Group size ranged from 3-7 members. The groups had to work together throughout the semester in order to deliver a group project for an Organizational Behavior course and data was collected in three successive academic years. During an interactive lecture on decision-making, the students were asked to participate in a decision-making exercise and perform a series of decision making tasks first individually and then in groups. The task consisted of 10 decision-making situations, adapted from experimental tasks designed to capture several heuristic and biases: the framing effect (2 items), representativeness bias (6 items), and Ellsberg's paradox (2 items) (Curșeu, 2006; Curşeu & Schruijer, 2012). Decision tasks were adapted in order to evaluate decision-makers' rationality, defined as the extent to which their choices are aligned with a normative ideal (Shafir & LeBoeuf, 2002). For each decision task, participants had to choose among several alternatives, and one of these alternatives was the normatively correct answer. An example of such decision-making task is: "You have the chance of buying a lottery ticket. Suppose that on the first ticket the numbers are 7, 12, 18, 24, 33 and 45 and on the second ticket, the numbers listed are 1, 2, 3, 4, 5 and 6. Which one do you think has the highest chance of being winner? a) The first ticket; b) The second ticket; c) Both tickets have equal chances of being a winner; d) I cannot decide".

Similar to Study 1, group members performed the task first individually (10 minutes) and then in groups (15 minutes). All teams received the same amount of time for the task and in order to prevent inter-group interactions, researchers made sure that students interacted only within groups and no cross talking occurred between groups. The decision-making score (summed number of correct answers on the 10 items) reflects the extent to which individuals and groups are rational in their decisions (the extent to which decisions are aligned with normative expectations). At the end of the exercise, students received the correct answers, were asked to reflect on their individual and group decision-making and were presented with an overview of heuristics and biases in decision making. Just as in the NASA Moon Survival task, we conceptualize cognitive distance as the distance between the highest score in the group and the rest. Therefore, similar with Study 1, the cognitive distance is computed via coefficient of variation adjusted for group size (Bedeian & Mossholder, 2000).

Additional analyses. Because our sample included respondents from different study years we have performed additional data analyses to explore systematic differences in synergy across the three years in which data were collected. We conducted a MANOVA analysis with study year as a factor and weak and strong synergy as dependent variables. For weak synergy F (3, 117) = .95, p=.41 while for the strong synergy F (3, 117) = .50, p=.68. The results indicate that there are no significant differences in terms of year of study for any of the types of synergy. On this basis we suggest that there are no systematic differences in neither individual nor group synergy across years.

2.5.2. Results

Similar to Study 1, analyses are based on intact groups and means, standard deviations and bivariate correlations are presented in Table 2.4. We tested our hypothesis using two OLS regressions. We used similar analytical procedures as in Study 1 and therefore in the first step we entered group size, SD, 1/Mean, and cognitive distance 1 and in the second step, we entered cognitive distance 1 squared[4] (Table 2.5.). While there is a curvilinear relationship between cognitive distance and weak cognitive synergy, no relation has been identified between cognitive distance and strong cognitive synergy. Therefore, the second hypothesis has been partially supported. The inflection point at which weak synergy starts decreasing is 0.06. The formula used is similar with the one in the first study.

2.6. General discussion

A key contribution of the current research is the exploration of a curvilinear relationship between cognitive distance as a group cognitive configuration on the one hand and weak and strong synergy on the other hand. Building on the model presented in Devine and Philips (2001) we argue that cognitive distance (as a group configuration defined as how detached is the best performing individual in the group from the rest of the group members) influences the extent to which groups are able to achieve cognitive synergy. We show that cognitive distance is an important antecedent of collective performance in tasks that combine disjunctive and collaborative elements (common tasks used in group synergy literature). Both studies reported in this paper indicate cognitive distance has an inverted U shape relationship with weak cognitive synergy.

[4] Similar to Study 1, we checked the potential influence of gender diversity upon our results. In doing this, we re-ran the analyses while controlling for diversity in terms of gender (Teachman's index). As including this control did not alter the pattern of our results, all analyses are reported without it.

Table 2.4. *Descriptive statistics and correlations for Study 2*

Variables		*M*	*SD*	1	2	3	4	5	6
1.	Group size	4.38	1.45						
2.	1/Mean	.24	.07	-.14					
3.	SD individual	1.49	.74	.06	-.21**				
4.	Cognitive distance1	.21	.13	-.36***	.32***	.71***			
5.	Cognitive distance1^2	.06	.08	-.26***	.21**	.33***	.65***		
6.	Weak synergy	.70	1.28	.07	-.15	.03	-.08	-.19**	
7.	Strong synergy	-.89	1.49	-.02	-.01	-.50***	-.42***	-.26***	.78***

Note: *p<.10.**p<.05.***p<.01

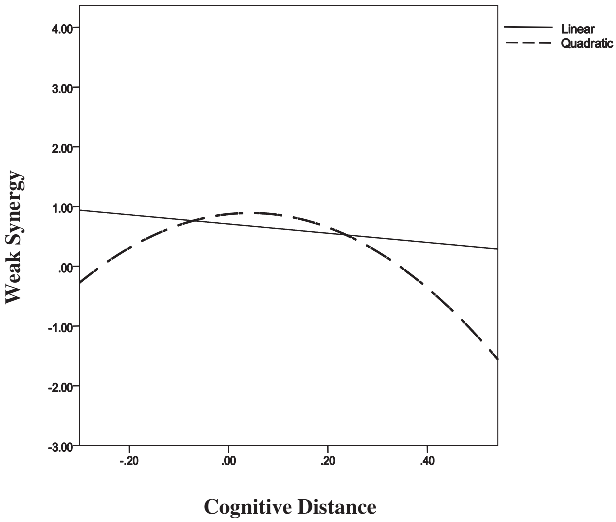
Table 2.5. *Results of regression analysis of group cognitive synergy on cognitive distance Study 2*

Step	Independent Variables	Strong Synergy Model 1 β	Strong Synergy Model 2 β	Weak synergy Model 1 β	Weak synergy Model 2 β
1	Group size	-.03	-.02	.03	.04
	1/Mean	-.10	-.11	-.11	-.13
	SD Ind	-.49***	-.51***	.05	.00
	Cognitive distance1	-.05	.02	-.06	.13
2	Cognitive distance1^2		-.09		-.24**
	F-value	10.69***	8.70***	.82	1.49*
	F-value change	10.69***	.79	.82	4.08**
	Adj R^2	.24	.24	0	.02

Note: for Study 2 *N* = 121; *p<.10.**p<.05.***p<.01

Group configurations with low and high cognitive distance are not able to perform better than the average individual performance of the group members. Groups with moderate levels of cognitive distance however have the highest chance of becoming better than the average performance of individual group members. These results are consistent across two different tasks (judgmental and decision-making task) and in relative terms at moderate levels of cognitive distance groups have the highest chance of achieving weak cognitive synergy. However, in absolute terms, groups manage to achieve weak cognitive synergy only in the second study, given that the synergy scores at moderate levels are higher than 0.

Figure 2.4. *The curvilinear relationship between cognitive distance and weak synergy in Study 2.*



Several explanations can be brought for the curvilinear association identified between cognitive distance and weak synergy. For instance, according to the hidden profile paradigm, high cognitive distance can be associated with low levels of weak synergy due to the fact that unshared/unique information is less likely to be discussed during group meetings than shared information (Gigone & Hastie, 1993; 1997). Given the above mentioned task structure and our conceptualization of cognitive distance, unique information reflects the task related expertise of the best performing individual in the group. Failure to integrate this expertise into the collective judgments or decisions leads to reduced chances of achieving cognitive synergy. On the other hand the best performing group member might experience a motivational loss and withdraw from the task due to the fact that (s) he perceives the distance between his/her own abilities and the rest of the group as difficult to deal with. The Kohler discrepancy effect indicates that group members are the most motivated to perform when they perceive moderate rather than high or low discrepancy between their own cognitive ability and the rest of the group (Messe et al. 2002). Moreover, when group members detain similar solutions for the task (small cognitive distance) they will be much more prone to reach early consensus and have a superficial processing of information (Karau & Kelly, 1992; Straus, Parker & Bruce, 2011). Therefore, a high alignment within groups leads to fast decision-making and a lack of consideration of available alternatives. Further on, the appropriateness of moderate cognitive distance for group synergy can be linked with cognitive consensus theory which states that a moderate level of consensus reflected in an equilibrium between similarity and diversity is the most beneficial for group performance (Mohammed, 2001). Insights from minority influence in groups show that contributions made by deviants (likely to be the role taken by best performing group members) are often disregarded due to the threat associated with dissent. Conditions that contributed to the diffusion of threat associated with dissent improve the acceptance of ideas expressed by deviants (Curșeu, Schruijer & Boroş, 2012) and moderate cognitive distance could be one of these conditions. These arguments are also in line with diversity research showing that collective performance is optimal at moderate rather than low or high levels of group diversity (Chi, Huang & Lin, 2009; Curșeu et al., 2012). To conclude, our results provide initial empirical evidence for a curvilinear relation between cognitive distance and levels of weak cognitive synergy in groups and future research should further explore the processes that explain this association.

Strong synergy is more difficult to achieve than weak synergy and it also might involve more complex forms of interpersonal interactions (Larson, 2010). In the judgmental task we have identified a curvilinear relationship between cognitive distance and strong synergy. This indicates that cognitive distance can be used to predict at which levels of distance collective performance is more likely to exceed the performance of the best individual in the group. However, these results should be interpreted with caution as in absolute terms the groups did not manage to exceed the performance of the most successful group member, given that the scores at moderate levels are not higher than 0.

The results on strong cognitive synergy reported in the first study might be influenced by the task type. In the NASA study groups had a task which involves a procedure of ranking among the items. The study of Hollingshead (1996) indicates that being required to rank-order all the choice alternatives (as opposed to picking the best one) encourages members to consider more of the information they collectively hold and therefore having more performance gains. Another reason could be the fact that in the NASA study, group members had to use the consensus technique while reaching their group solution. Several studies indicate that strong synergy can be substantially increased as a result of group processes support (Henry, 1993; Reagon-Cirinciore, 1994; Curșeu, Jansen & Chappin, 2013). Another reason for which we might have found a curvilinear relationship between cognitive distance and strong cognitive synergy in the first study but not in the second is the nature of the task. In the judgmental task group members are distant with respect to task-related knowledge while in the decision-making task group members differ in terms of their ability to rationally process information. For instance, demonstrating that matches are not useful on the moon depends on the group's knowledge that there is no oxygen on the moon. This type of demonstration comes more at hand than demonstrating that chance is not self-correcting, a key characteristics in some of the decision making tasks in Study 2.

Given the difficulties identified in achieving group strong cognitive synergy one related line of research could investigate the development of synergistic performance gains over time. Strong synergy might be difficult to capture in cross-sectional studies. In complex tasks, the synergistic performance might require repeated interactions among group members, so that aspects related to knowledge and patterns of behavior enacted in specific situations are shared (Larson, 2010). Future research should therefore capture factors conducive for strong cognitive synergy.

Overall, our study brings several contributions to the group dynamics literature. First, it contributes to the cognitive diversity stream of research by investigating configurations of distance in abilities as an antecedent for group cognitive synergy. This reflects the distribution of individual judgments with respect to a content (Study 1) or information-processing related task (Study 2). Therefore the configuration lies in the already given individual solutions and not in knowledge that might be relevant for the task as it is the case in the diversity literature. Second, it contributes to the group synergy literature by showing that at moderate levels of distance groups have the highest chances of achieving cognitive synergy. Although in absolute terms cognitive synergy is difficult to achieve, our studies indicate that the curvilinear relationship gives a meaningful indication for levels of cognitive distance (high, medium, low) that are the most conducive for cognitive synergy. Next to these, while integrating theory on cognitive diversity and group cognitive synergy we emphasize the salience of cognitive distance for group synergy. As high cognitive distance implies that one group member is closer to the correct solution than the other group members, the key for achieving strong group synergy is to identify the best performing group member and improve his/her performance. Sniezek (1989) shows that among other techniques, the technique of the dictator (where group members were explicitly required to identify their best member and follow him) was the most efficient in generating strong cognitive synergy. Also, having one out-of-the-range score might also motivate group members to reconsider their judgments and think out-of-the-range. Thinking out-of-the-range is particularly relevant when groups strive to outperform their best performing member, thus in the case of strong synergy (Larson, 2010).

Another contribution of our study is the attempt to test the association between cognitive distance and group synergy across two different types of tasks (judgmental and decision-making) both tasks having disjunctive and collaborative elements. In line with Larson's (2010) conceptualization of group synergy across tasks, we validate our results by showing that cognitive distance has an inverted U shape relationship with weak cognitive synergy not only in a judgmental task but also in a decision-making task. For strong synergy however, the non-linear relation was supported only for the judgmental task. The inherent complexity of the relationship between configural group properties and performance (Kenny & Garcia, 2012) in combination with the failure to fully replicate the results for strong synergy across the two tasks suggests that future research is warranted.

Next to the contributions, the study has also a few limitations. First, the task is a divisible type of task composed of a series of disjunctive subtasks. It is possible for groups to rely on different members for different components of the task and for group performance to exceed the level of the best member. However, information integration and input from all group members is essential for high performance in such tasks (Hall & Watson, 1970) therefore our results yield valuable conclusion for groups in general. Future research needs to further explore the way cognitive distance impacts on performance in other types of tasks like conjunctive tasks, where group performance is dependent upon the least competent member of the group. Second, the task used to evaluate cognitive synergy in Study 2 (scores range from 0 to 10) raises the question of what happens if the group is composed of individuals obtaining the highest possible score on task performance. This particular group configuration is a boundary condition (especially for the type of task used in the second study) as the group as a whole although composed of competent individuals, cannot achieve neither strong nor weak synergy. This particular group configuration did not occur in our sample, yet in theory it is a possible group configuration. We checked for this ceiling effect for strong group synergy in Study 2 and ran additional analyses without the groups in which one of the group members scored 10 on the individual decision task. The additional analyses yielded similar results and we can therefore conclude that the above mentioned boundary condition is less problematic for this particular sample. Third, we used students groups engaged in collaborative learning and the underlying goals and motives of students engaged in collaborative learning tasks may differ from those of group members in other organizational settings, where performance related pressures are higher and cognitive distance may have different effects on group cognitive synergy.

Therefore, future research should try to replicate our findings in other organizational groups or use participants with various backgrounds and underlying social motives. Fourth, as we reorganized our regression equations based on Harrison and Klein (2007), the simultaneous inclusion of within group mean, standard deviation, coefficient of variation and squared coefficient of variation as predictors generates multicollinearity problems. We have tried to solve this issue, more important in Study 1, by using a heuristic alternative to compute cognitive distance, yet future research could further explore ways in which cognitive distance can be operationalized in ways that would not generate multicollinearity. Finally, our results do not specifically shed light on the processes underlying the curvilinear effects identified in our study. Therefore, further studies should investigate which are the possible processes that generate the highest group performance at moderate levels of cognitive distance. Motivational factors might play a role here given that distance in ability has been found to have an inverted-U shaped relationship with motivation to get involved in the task (Messe et al., 2002). Other factors such as the level of rejection of the highly detached group member or the level of cross-understanding experienced by the groups might explain the negative relation between group cognitive synergy and high cognitive distance.

2.7. Conclusions

Our study indicates that cognitive distance is a meaningful antecedent for group cognitive synergy. Although at moderate levels groups have the highest chances for becoming better than their average and best individual member, in absolute terms reaching synergy is rather a difficult task. Further studies should investigate under which conditions (e.g. decision rules, Curșeu, Jansen & Chappin, 2013) groups manage to push their performance beyond the one elicited by its average and best performing group member.

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Chapter 3

ARE BALANCED GROUPS BETTER? BELBIN ROLES IN COLLABORATIVE LEARNING GROUPS[5]

3.1. Introduction

Modern organizations use groups to perform a variety of complex tasks (Tannenbaum, Mathieu, Salas & Cohen, 2012), therefore, next to job-related knowledge and expertise, teamwork skills become important elements in personnel selection across a variety of organizational fields (Burch & Anderson, 2004; Stevens &Campion, 1994; Zedeck & Goldstein, 2000; O'Neil, Allerd & Baker, 1997). As a consequence, educational programs extensively use collaborative learning to help students develop teamwork skills (Curșeu, Janssen & Raab, 2012) and acquire specific curricular knowledge (Haugwitz, Nesbit & Sandmann, 2010; McCune & Entwistle, 2011; Curșeu, 2011). It becomes therefore important to identify group design features that influence the effectiveness of individual and collaborative learning in student groups (Curșeu & Pluut, 2013).

One of the most extensively used design tool for groups is based on the group roles preferences described by Meredith Belbin (1981). Group roles preferences are defined as group members' predispositions to adopt specific patterns of behaviors in interpersonal interactions and these stable individual differences can configure in various ways within groups (Belbin, 1981). While roles taken individually have no predictive value for teamwork quality and performance - given that they do not reflect the interactional nature of groups – the ways in which these roles combine within groups fulfill this function and thus make role preferences a configural property (Klein & Kozlowski, 2000) that can be used to design effective groups. One of the major claims of Belbin's role theory

[5] This chapter is based on: Meslec, N. & Curşeu, P.L. Are balanced groups better: Belbin roles in collaborative learning groups. Manuscript under review.

is that balanced groups (in which all nine roles are present) perform better than unbalanced groups, in which existing roles are duplicating each other (Belbin, 1981). Although the claim of balanced groups is being extensively used in organizational consultancy, the empirical evidence supporting its validity is not conclusive (Senior, 1997; Partignton & Harris, 1999; Water, Ahaus & Rozier, 2008; Jackson, 2002; Blenkinsop & Maddison, 2007). The aim of the current paper is two-folded. First, we are aiming to test the role balance claim in an educational setting given that there is evidence supporting that Belbin's group role theory can be applied to non-managerial personnel as well (Fisher, Hunter & Macrosson, 1998). In doing this, we use a comprehensive approach in which we analyse the effect of various group balance indices on a wide array of outcomes in collaborative learning groups: teamwork quality, group cognitive complexity, and group performance, across time. Second, preferences for group roles have been shown to be gender-biased, such that some roles are more likely to be assumed by one gender than by the other (Sommerville & Dalziel, 1998; Anderson & Sleep, 2004). The second aim of our study is to disentangle the interplay between group role preferences and gender (percentage of women in particular) as well as their impact on group performance.

3.2. Theoretical underpinnings

Apart from their functional role (prescribed through design), group members have the tendency to display particular behavioral patterns in interpersonal interactions that aim to facilitate the progress of the group towards specific task achievement. These stable individual differences are captured by the group role preferences (Belbin, 1981). The root of group roles were considered to lie in a person's generic personality traits and mental abilities (Belbin, 1981; Aritzeta, Swailes & Senior, 2005) as well as the structure of environment (Arroba &Wedgwood-Oppenheim, 1994; Fisher & Macrosson, 1995; Yuwei & Tang, 1997). In the context of a 9-year research project developed by Belbin, behavioral observations as well as personality and mental abilities of group members were recorded and used to develop a taxonomy of group role preferences. The matching of these measurements resulted in the identification of eight possible group roles: the coordinator (CO- co-ordinates and controls the activities of the group), the resource-investigator (RI-extrovert, makes outside contacts and develops ideas), the teamworker (TW-person oriented, communicates well with the others), the plant (PL-creative and imaginative), the monitor-evaluator (ME-prudent and analytical), the implementer (IM-practical and task-oriented), the completer-finisher (CF-attentive to details, finishes things), and the shaper (SH-dynamic and challenging). Later on, a ninth role was added, the specialist (SP-with high technical skills and in-depth knowledge for the task) (see Belbin, 1981; 2009 for an extensive description).

One of the most important claims in Belbin's work is that balanced groups (with regard to their members' role preferences) have superior performance to unbalanced groups. In other words, it is useful to have members that possess strengths without duplicating the ones already present in the group (Belbin, 1981; Water, Water & Bukman, 2007). A perfectly balanced group would be a group in which all nine roles are present in a high or very high level while a perfectly unbalanced group would be one in which all the group members have the same role preference. The concept of role balance is therefore a configural property of groups (Klein & Kozlowski, 2000), and the configuration of roles are predictive for group dynamics and performance (Belbin, 1981). According to the Input-Process-Output model of group effectiveness (Ilgen, Hollenbeck, Johnson & Jundt, 2005), group roles configurations can be considered inputs that predict the group processes and the quality of interpersonal interactions, which in turn influence group performance. However, studies investigating the impact of group role balance on performance are not conclusive. While some studies identified little or no relation between the two (Senior, 1997; Partignton & Harris, 1999; Water, Ahaus & Rozier, 2008; Jackson, 2002; Blenkinsop & Maddison, 2007), some others found evidence for group balance as a valid predictor of group performance (Higgs, Plewnia & Ploch, 2005; Prichard & Stanton, 1999).

The lack of converging results can be due to several factors. First, in most of the studies there is no control for group size and gender diversity. Studies indicate that there are gender differences regarding group role preferences (Anderson & Sleap, 2004). Next to the gender issue, some of the group balance indexes are also sensitive to the group size (Water, Water & Buckman, 2007). Therefore, gender and group size should be accounted for when analyzing the relation between balance and performance. Second, little specifications were given with respect to how group balance can be computed. Therefore, there is little overlap in the formulas currently used in computing group balance. Group balance was computed while considering the behavioral or environmental focus of the roles (Higgs, Plewnia & Ploch, 2005), the weights of the top three roles an individual in a group has (the so-called primary, secondary and tertiary roles) (Water, Ahaus, Rozier, 2008) or how much the group deviates from an ideally balanced group (Partington & Harris, 1999). The different assumptions underlying group balance formulas could stand as an explanation for the non-conclusive results for the group balance-group performance relation. Finally, most of the studies used just one indicator of performance, which differed across studies. For instance, performance was measured in terms of group processes such as group organisation and communication (Blenkinsop &Maddison, 2007; Prichard & Stanton, 1999) subjective measures of managers (Higgs, Plewnia & Ploch, 2005) or group success in simulation games (Partington & Harris, 1999; Water, Ahaus, Rozier, 2008).

In the current study we strive on the one hand to reconsider the concept of group roles balance and its impact on performance while overcoming the limits described above. Therefore, we test the impact of group role balance while using several balance indices (which rely on different assumptions) upon a variety of performance indicators (group processes, group cognitive complexity, perceived and actual group performance). On the other hand, we are aiming to explore in greater detail the potential influence of gender on group role preferences and the impact of this interplay on group performance.

3.3. The impact of group role balance upon teamwork quality

Teamwork quality (TWQ) is a multidimensional construct that reflects the quality of interactions inside the group. It consists of several dimensions that reflect both group processes (communication, coordination and planning) and group emergent states (cohesion, perceived performance and potency) (Curșeu, Schalk & Schruijer, 2010; Hoegl & Gemuenden, 2001; Curșeu & Pluut, 2013).

Experience with teamwork and synergetic interactions inside the group in an educational setting comes with several advantages. First, organizations are often employing groups and teamwork as a form of organizing and therefore are looking for candidates that already acquired teamwork skills during their educational trajectory (Chen, Donahue & Klimosky, 2004). Thus, experience with teamwork increases workforce readiness given that students develop during their studies specific teamwork knowledge, skills and abilities. Second, when groups manage to develop synergetic interactions (good teamwork quality) they benefit of complex group knowledge representations (Curșeu & Pluut, 2013) as well as increased group performance (in innovative projects) and at a personal level are able to learn more (in terms of knowledge and skills) and be more satisfied with their work (Hoegl & Gemuenden, 2001).

Given the benefits of teamwork quality, a lot of effort has been put in investigating how the quality of group interactions can be improved in educational settings (Chen, Donahue & Klimosky, 2004; Curșeu & Pluut, 2013; Curșeu, Janssen & Raab, 2012). Solutions such as the development of university courses in which students specifically learn about teamwork (e.g. The Psychology of Working in Groups and in Teams) (Chen et al., 2004) or personality student-group interventions in which group members learn about each other's personalities and how to manage individual differences (Clinebell & Stecher, 2003) were proposed.

A more straightforward solution is the use of design principles that generate the most effective group configurations. However, the simple placement of students in groups does not always guarantee the development of teamwork skills (Hansen, 2006; Johnson & Johnson, 1990). Student groups often experience unclear goals, mismanagement, conflicts or unequal participation (Cox & Bobrowski, 2000; McCorkle et al., 1999; McKendall, 2000; Rau & Heyl, 1990). In the current study we would like to investigate whether composing groups under the role balance assumption leads to better group interactions and thus higher teamwork quality.

According to Belbin roles theory, group role balance, as a configural group property should have a positive impact on teamwork quality. A crucial role here is played by social roles such as coordinator and teamworker. Being associated with the extroversion dimension of personality (Davies & Kanaki, 2006), such roles facilitate communication and coordination processes inside the group. The compromising style of conflict management (Aritzeta et al., 2005) associated with these roles also buffers emergent relationships conflicts and leads to positive states such as group cohesion. The resource-investigator, characterized by over-optimism not only contributes to the group's believe in their own strengths but, also helps in collecting and bridging among different ideas, including those of introverted group members (e.g. plants or specialists).

Effective teamwork requires a balance between task related and interpersonal knowledge as research on shared mental models argues that members of effective groups need to share both task related as well as teamwork related knowledge (Cannon-Bowers & Salas, 2001). The convergence of teamwork and taskwork mental models is conducive for effective teamwork processes which in turn impact on group performance (Mathieu et al., 2000). Moreover, meta-analytical evidence also suggests that shared mental models have a positive influence on the quality of interpersonal processes within groups (DeChurch & Mesmer-Magnus, 2010). A balanced role composition secures that both task related (e.g. specialist, plant) as well as teamwork related (e.g. teamworker, resource investigator) orientations are simultaneously present and as such balanced groups are expected to have more effective interactions than unbalanced groups. Therefore, the fine adjustment of one role to another in a balanced group should lead to synergistic teamwork processes. We hypothesize the following:

H1. Group role balance positively predicts teamwork quality.

3.4. The impact of group balance upon group outcomes

Next to perceived group performance and objective performance we also use group cognitive complexity (GCC) as an outcome variable. Group cognitive complexity (GCC) has been defined as 'the richness of the collective knowledge structures that emerge as a group-level phenomenon from the integration of individual specialized knowledge through interpersonal interactions' (Curșeu et al., 2010). The higher the cognitive complexity, the stronger the group's capabilities to absorb the variety of representations held by group members in relation to the task or the environment (Neill & Rose, 2006) and the higher group performance (Curșeu et al., 2010).

Research to date investigated how GCC and performance can be stimulated in collaborative learning groups. Factors such as the composition of groups with respect to gender, personal values, teamwork quality and conflict have been found to play a key-role for group's cognitive complexity and performance (Curșeu & Pluut, 2013; Glew, 2009; Curșeu, Janssen & Raab, 2012). In line with the claim developed by Belbin (1981) we would like to investigate whether a configural group roles property such as role balance leads to higher cognitive complexity and performance in groups. According to Belbin (1981), useful people to have in groups are those who have unique characteristics and do not duplicate the ones already present in the group. A pure group (in which all group members detain the same role) will develop a style of its own, focused only on task or relational domains and as such will not foster performance (e.g. a group of CW will be well organized but with a lack of real ideas and inflexibility). Therefore, a balanced group in which all nine roles are present will contain all the characteristics needed for group performance. In line with Belbin's balance claim, we hypothesize the following:

H2. Group balance will positively predict group outcomes (GCC, perceived and objective group performance).

3.5. Teamworker role preference and teamwork quality as mediators

Next to the group role balance concept, Belbin proposes also a thematic distinction of his roles. He argues that although the nine roles are distinct, three thematic patterns can be distinguished: social (CO, RI, TW), mental (PL, ME and SP) and action roles (IM, CF, SH) (Belbin, 2009).

Women have a stronger preference for social roles than men and are more likely to assume these roles in a group. From the social roles, women have been found to have a stronger preference for the role of teamworker (Sommerville & Dalziel, 1998; Anderson & Sleep, 2004) than men. Teamworkers have been characterized as cooperative and diplomatic, being able to listen carefully to the other group members and avoid confrontations (Belbin, 1981). This comes in line with the gender-role theory that indicates that prototypical women are more often associated with communal attributes (e.g. concern with the welfare of other people) than men (Eagly & Karau, 2002). Through their strong relational orientation women increase groups' capacity to harmoniously work together and as a consequence their capacity to achieve better cognitive outcomes (Woolley et al. 2010). Empirical evidence shows that the percentage of women in a group is conducive for emergent group level cognitive competencies through their increased social sensitivity (Woolley et al., 2010) and gender diversity is also beneficial for the emergence of group cognitive complexity (Curșeu & Pluut, 2013). Previous research also reported small to medium positive effects of gender diversity on collaborative learning effectiveness (Curșeu & Pluut, 2013; Pluut & Curșeu, 2013). Due to their higher social sensitivity (Woolley et al., 2010) and their effective way of coping with power differences in groups, women stimulate and maintain a harmonious interpersonal climate within groups that ultimately increases group performance. We therefore argue that the percentage of females in a group positively links to performance and cognitive complexity and this relation is mediated by the quality of group members' interactions (teamwork quality) on the one hand and the preference for the teamwork role on the other hand.

H3. Teamwork quality mediates the impact of percentage of females on GCC and objective group performance.

H4. The percentage of women impact on teamwork role preference which in turn impact on group cognitive complexity and group performance.

3.6. Method

3.6.1. Sample and procedure

The sample consisted of 459 students (151 female) enrolled in an Organizational Behavior course at a Dutch university. Participants were asked to form groups at the onset of the course. Group size ranged from three to seven members, resulting in 84 groups. The vast majority of the groups had five or six members. For a detailed overview of demographics see Table 3.1. The more extreme group sizes (three and seven) resulted from the constraints imposed by the number of students enrolled for each of the workshops. Groups had to work together throughout the semester in order to deliver three group assignments which consisted of three case studies that covered 40% of their individual grades. We used a cross-lagged design, data being collected across fourteen weeks, period which was indicative for the duration of the course. Data collection involved groups belonging to three different cohorts of students which were taking the course in three distinct academic years. Group roles (as a configural property of groups) have been assessed in the first week of the semester. Close to the end of the semester, teamwork quality, perceived performance and group cognitive complexity have been assessed. Finally, at the end of the semester, group performance has been measured as the combined score for the three group assignments. The separation of measurement in time has the advantage of reducing the common method bias (Podsakoff et al., 2003).

Table 3.1. *Sample demographics*

Group size	Number of women/group						Total
	0	1	2	3	4	5	
3	1	0	0	1	0	0	2
4	0	4	1	0	0	0	5
5	4	8	15	7	0	0	34
6	4	6	17	6	3	1	37
7	1	1	2	1	0	0	5

3.6.2. Measures

Belbin Roles Questionnaire and Role Balance Indices. Group roles have been assessed using an adaptation of the role self-assessment instrument developed by Belbin (BTRSPI) (Belbin, 1981). The questionnaire (Belbin's team role questionnaire) was part of the student's handbook and contained items referring to all nine Belbin roles, including the specialist role which was not present in the 1981 version of BTRSPI (Huczynski & Buchanan, 2001). The instrument has seven sections and each section contains nine items, one for each of the nine roles. For each section, participants had to distribute ten points across the nine items, considering the behavior that best describes him in a group. At the end, for each group member a score is computed for each of the nine roles. Each role score is computed by adding up the points allocated to the seven items that were referring to that particular role. Theoretically, each role score can take values between 0-70.

In order to test the claim that balanced groups perform better, we reviewed all the balance indices proposed in the literature and used the ones which were presented detailed enough in order to be replicated. In addition, we added up a new balance index and also other (thematic) role patterns indices proposed in the literature. The balance indices (TB) and role thematic patterns (TP) are described below.

The first balance index (TB1) relies on the assumption that in a balanced group the aggregate score from all members will be evenly spread across the nine roles (Partington & Harris, 1999). TB1 is computed with the following formula: TB1 = $9/[(\sum R-7.77)+9]*100$, where R represents each of the nine roles, summed up at a group level. Thus, TB1 considers the amount of roles directly at a group level, disregarding their original configurations at an individual level. A perfectly balanced group would have an R on each role equal to 7.77. This score represents the 70 points to be distributed divided by the nine roles. If the total deviation of the role mean from 7.77 is 0, then TB1=100%.

The premise for the second balance index (TB2 and TB2a) is that a balanced group would have at least one person scoring high or very high in as many as possible of the nine roles (Partington & Harris, 1999). For each role, norms for defining high and very high scores have been computed. *TB2* uses the norms defined by Belbin (1981, p.158) while TB2a uses the norms constructed for this particular study. For each role, all the individual scores are ordered from the smallest score to the highest. The scores are split in four quartiles, the highest two quartiles (from 66-100%) containing the range of scores which qualify as high and very high scores for that particular role. The norms for this study were similar with the ones identified by Belbin (1981, p.158) and Partington & Harris (1999, p. 700). Each group received a maximum of one point for each role represented in a high or very high level and two points if the role was not represented in a high or very high level. The following formula has been used TB2= $(9/\sum HR)*100\%$, where HR represents the sum of points given for each role represented in a high or very high level.

The third balance score (TB3) has been computed on the premise that ideally roles should not be duplicated (Belbin, 1981; Partington & Harris, 1999). The formula used is similar with the one for TB2, TB3 = $(9/\sum HR)*100\%$. The difference lies in the number of points given for each role. In the case of TB3, each role represented in a high or very high level counts for the number of points given.

Finally, the last balance index (TB4) considers group roles as a qualitative property of the groups, in which both the richness of roles represented in the group and the abundance of the roles making up the richness are considered. Each group received one point for each role represented in a high or very high level and 0 points for roles not represented as so. Group balance has been computed while using Simpson's index of diversity $1 - D = \sum n(n-1)/N(N-1)$, where n is the total number of high and very high scores of a particular role and N is the total number of high and very high scores of all roles (Simpson, 1949).

To summarize, we have used four group balance indices, each of them being based on different theoretical considerations. The first balance index TB1 accounts for Belbin roles directly at a group level while TB2 and TB2a consider roles at an individual level which are afterwards configured at a group level. TB3 is similar to TB2, bringing in addition a correction for roles that duplicate each other. Finally, TB4 attempts to account for Belbin roles in a more comprehensive way, while considering both the variety of roles represented in the group as well as their intensity.

Next to the group role balance, Belbin proposes the existence of three thematic patterns (TP): social (CO, RI, TW), mental (PL, ME and SP) and action roles (IM, CF, SH) (Belbin, 2009). We decided to include this last distinction into our analysis. For each thematic category a group score has been computed while averaging the individual scores to the group level. For instance, for the social thematic pattern, $TP_{social}=(\sum CO_{IndScores}/GroupSize+\sum RI_{IndScores}/GroupSize+\sum TW_{IndScores}/GroupSize)/3$, where IndScores represents the individual score for that particular role.

Teamwork quality (TWQ). Groups had to rate their own teamwork quality on a 5-point scale questionnaire in which the following group-related variables have been included: communication (4 items, Eby et al., 1999), cohesion (4 items, Carron, Widmeyer & Brawley, 1985), coordination (5 items, Eby et al., 1999), planning (5 items, Curșeu, et al., 2010), perceived performance (2 items, Curșeu et al., 2010) and potency (3 items, Guzzo et al., 1993). Data has been collected directly at a group level, group members being asked to reflect upon their own teamwork processes during the semester and decide upon a group rating for each of the teamwork items. The average score of all the scales has been used as an indicator for TWQ. Data collection through group agreement has been argued to be superior to individual data collection which is afterwards aggregated at a group level (Kirkman, Tesluk & Rosen, 2001). The Alpha Cronbach for teamwork quality construct was higher than .80, which indicates a good reliability of the scale. The teamwork instrument has been administered one time close to the end of the course.

Group Cognitive Complexity (GCC). Group cognitive complexity was measured through the cognitive map technique that is a group task (Curșeu et al., 2010). Groups received 20 cards on which major concepts from the course domain were written. Their task was to organize the concepts in a way that reflects their understanding as a group of the relation between the concepts. Once agreed upon the final chart, they had to glue the cards on a paper and draw the relations between the concepts as well as to indicate the type of relation between the concepts. The final maps have been assessed while using three criteria: total number of concepts used (NoC), total number of connections established between the concepts (CMC) and the number of distinct relations established (CMD). These three dimensions are indicative for group complexity as complexity of conceptual systems has been referred to as including on the one hand the number of dimensions belonging to the system and one the other hand the nature and the extent of rules elicited for integrating these dimensions (Curșeu et al., 2010; Calori, Johnson & Sarnin, 1994). The type of relations has been rated using seven different categories: association, equivalence, topological, structural, chronological, and hierarchical (Curșeu et al., 2010; Gomez et al., 2000). Group cognitive complexity has been computed after the following formula CMCo= (CMCxCMD) /NoC (Curşeu et al., 2010).

Group Performance. Perceived performance has been measured with the same scale as the one included in the TWQ questionnaire. For objective performance we have used the grades obtained by the groups at three different assignments. Groups had to deliver three assignments, which represented 40% of their final grade. In the three assignments, groups had to analyze and solve three case studies while using topics studied during the course (motivation at work, leadership and group dynamics). The maximum grade for the first assignment was 10 points while for the other two assignments they could have earned a maximum of 15 points. The performance score has been computed as the average score of the three grades.

3.6.3. Control variables and data analysis strategies

In order to test our first two hypotheses we ran several OLS regression models with group balance indices and thematic patterns as predictors and teamwork quality, group cognitive complexity and group performance (objective and perceived) as dependent variables. We have run a separate model for each of the four dependent variables and for each of the group balance indicators. Empirical evidence shows that there are significant differences between men and women in group roles assumed (Anderson & Sleap, 2004). Moreover, gender diversity impacts on the emergence of collective cognitive competencies (e.g., group rationality, Curşeu, Jansen & Chappin, 2013) and group cognitive complexity (Curşeu, Schruijer & Boroş, 2007). In order to control for the potential influence of gender diversity upon our results we ran the analysis while controlling for both gender diversity and the percentage of females in each of the groups. Gender diversity reflects the distribution of male and female inside the group, with higher scores reflecting an equal distribution of the two genders in the group. Gender diversity index has been computed using Teachman's index (Teachman, 1980). Given that some group balance indices are sensitive to the number of members a group has (Water, Water & Buckman, 2007), group size has also been used as a control variable.

In order to test our last two hypotheses we have ran two mediation models by using the nonparametric resampling procedure of bootstrapping developed by Preacher & Hayes (2008). We have ran two separate models, one for each of our two dependent variables (group cognitive complexity and objective group performance). We used group size as a control variable, percentage of females as independent variable and preference for the teamworker role and teamwork quality as mediators. This method has the advantage of specifying and testing a single multiple mediation model at the same time and thus is particularly useful for models that contain more than one mediator, as it is the case of our study. With this procedure one mediation effect is estimated while the other mediation effects are accounted for. This comes with the following advantages 1) it limits parameter bias due to omitted variables 2) it offers the possibility to determine the relative magnitudes of the indirect effects associated with all mediators (Preacher & Hayes, 2008).

3.7. Results & Discussions

3.7.1. Correlational findings

As expected, objective group performance correlates positively with perceived performance, $r(84)=.40$, $p<.05$, and teamwork quality, $r(84)=.28$, $p<.05$ (Table 3.2.). This comes in line with previous studies indicating that effective teamwork interactions is beneficial for the overall performance of the group. The meta-analysis of LePine et al. (2008) indicates that teamwork processes are positively associated with both group performance and members' satisfaction.

Group size is not associated with TB1, $r(84)=.06$, $p>.05$, and positively associated with TB2, $r(84)=.46$, $p<.05$, and TB2a, $r(84)=.26$, $p<.05$. The higher the group size is, the better the chances of the group are to reach group role balance, which involves the representation of all nine roles at a high or very high level.

However, this reasoning does not hold for TB1 where the representation of roles are counted directly at a group level. Thus, group size is not as relevant for TB1 as it is for TB2 and TB2a. Group size further links negatively with TB3, $r(84)=-.32$, $p<.05$, and TB4, $r(84)=-.32$, $p<.05$. TB3 and TB4 although similar to TB2 in counting the roles which are represented at a high or very high level, also include corrections for roles that are duplicating each other and respectively for the intensity of roles. These corrections could explain why the link with group size is negative.

Gender diversity is positively associated to group cognitive complexity, $r(84)=.25$, $p<.05$. This comes in line with previous studies indicating that gender-diverse groups are more likely to benefit from different perspectives, ideas and experiences of their members (Curşeu et al., 2010; Curşeu & Pluut, 2013). Percentage of women is also positively associated to group cognitive complexity, $r(84)=.25$, $p<.05$. These last two associations come in line with previous findings indicating the important role of gender for groups and group performance (Woolley et al., 2010).

Finally, some significant correlations between the group balance indexes have been identified. TB2 and TB2a, $r(84)=.39$, $p<.05$, TB2a and TB4, $r(84)=.53$, $p<.05$, TB3 and TB4, $r(84)=.33$, $p<.05$. TB1 does not correlate with any of the other balance indexes, given that the index is constructed while using a different assumption, in which group roles are considered directly at a group level.

3.7.2. The impact of role balance on group performance indicators

In order to test our first two hypotheses we ran several regression models with group balance indices and thematic configurations as predictors. A separate regression analysis has been conducted for each of the dependent variable. Group size, gender diversity and percentage of females have been used as control variables. Overall, our results (Table 3.3.) indicate that group balance does not relate in the predicted direction with any of the four outcome indicators.

Table 3.2. *Descriptive statistics and bivariate correlations at group level*

Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Group size	5.46	.79	3.00	7.00															
2. Gender diversity	.53	.22	0	.69	.10														
3. Percent females	33.66	20.01	0	100	-.11	.58***													
4. TB1	99.99	3.71	88.21	116.33	0.06	.08	.05												
5. TB2	79.61	8.61	61.53	100	0.46***	.08	.00	.03											
6. TB2a	81.87	6.37	66.67	88.89	0.26**	.17	.11	.06	.39***										
7. TB3	54.76	7.38	38.10	72.73	-.32***	-.22**	-.09	-.01	.13	.02									
8. TB4	.90	.02	.85	.94	-.32***	-.04	.06	.08	.03	.53***	.33***								
9. Relationship roles	8.03	.87	6.13	12.08	-.19	-.10	.00	-.36***	-.08	-.16	.19	-.21**							
10. Acting roles	8.81	.95	6.60	12.17	.09	.26**	.07	.19	.21	.05	-.16	-.05	-.47***						
11. Thinking roles	6.47	.93	3.17	8.80	.07	-.17	-.07	.02	-.14	.09	-.02	.25**	-.41***	-.59***					
12. TWQ	19.06	1.58	14.47	23.20	.12	.09	.21	-.19	.03	-.10	.00	-.17	.12	.08	-.17				
13. Perceived performance	3.88	.58	2.50	5.00	.22	.09	.09	-.02	.08	.01	-.10	-.08	-.11	.21	-.10	.59***			
14. GCC	2.64	.89	.60	5.70	.15	.25**	.25**	.28***	.16	.04	-.08	-.15	.04	.08	-.14	.08	.14		
15. Performance	10.59	1.27	7.67	12.83	.15	.12	.07	-.02	.07	-.01	.03	.04	-.01	.07	-.05	.28**	.40***	.18	

Note: *p<.10**<.05***<.01

Table 3.3. *Impact of group balance and thematic configuration roles on four types of group outcomes*

Step	Variable	Teamwork Quality β	Teamwork Quality ΔR^2	Perceived performance β	Perceived performance ΔR^2	Cognitive Complexity β	Cognitive Complexity ΔR^2	Group Performance β	Group Performance ΔR^2
TB1									
1	Group size	.20*	.04	.23**	.02	.15*	.06	.15*	0
	Gender diversity	-.08		0		.10		.08	
	Percent females	.29**		.12		.14		.04	
2	TB1	-.22**	.08	-.04	.01	.25***	.11	-.04	0
TB2									
1	Group size	.22*	.04	.24*	.02	.12	.06	.14	0
	Gender diversity	-.09		0		.12		.08	
	Percent females	.28**		.12		.14		.04	
2	TB2	-.07	.03	-.02	.01	.09	.05	0	0
TB2a									
1	Group size	.23**	.04	.25**	.02	.17*	.06	.17*	0
	Gender diversity	-.07		0		.12		.08	
	Percent females	.30**		.12		.16		.05	
2	TB2a	-.17*	.05	-.07	.01	-.03	.05	-.08	0
TB3									
1	Group size	.20*	.04	.23**	.02	.17*	.06	.18*	0
	Gender diversity	-.08		0		.12		.10	
	Percent females	.28**		.12		.15		.04	
2	TB3	.05	.03	0	.01	.01	.05	.12	0
TB4									
1	Group size	.13	.04	.23**	.02	.13	.06	.18*	0
	Gender diversity	-.10		0		.12		.08	
	Percent females	.29**		.12		.15		.03	
2	TB4	-.16*	.05	-.01	.01	-.11	.06	.10	0
Action roles									
1	Group size	.17*	.03	.21**	.02	.14*	.05	.14	0
	Gender diversity	-.10		-.07		.13		.06	
	Percent females	.28**		.14		.14		.04	
2	Action roles	.05	.03	.22**	.05	.02	.04	.05	.01
Thinking roles									
1	Group size	.20*	.04	.25**	.02	.18*	.06	.15*	0
	Gender diversity	-.13		-.03		.10		.06	
	Percent females	.30**		.13		.15		.04	
2	Thinking roles	-.18*	.06	-.14	.03	-.12	.06	-.06	.01
Relationship roles									
1	Group size	.21*	.03	.21*	.02	.16*	.05	.15	0
	Gender diversity	-.06		0		.15		.08	
	Percent females	.27**		.12		.13		.04	
2	Relationship roles	.17*	.05	-.07	.01	.09	.05	.01	.01

Note: *p<.10**<.05***<.01;

TB1 appears to be the only group balance index that predicts teamwork quality and GCC. What differentiates TB1 from the other balance indexes is that roles are not considered at an individual level first and then summed up at a group level but, rather as configurations of roles directly at a group level. For example, for the coordinator role all the points belonging to all group members (whether they are high or low) are being summed up and considered for the balance assumption. The rest of the formulas start from the assumption that one particular role (e.g. coordinator) should be represented in a high or very high level at one particular group member and that should be considered for the group balance. The low scores belonging to other group members to that particular role are not being accounted for. The positive link between TB1 and GCC (β=0.25, $t(81)$=2.42, p<.05) indicates that group balance considered as a configural group property and not as a sum of individual roles appears to predict the level of cognitive complexity of the group. This result comes in line with previous findings indicating that in low complexity tasks the link between group role balance and performance is negative while in high complexity tasks this link becomes positive (Higgs, Plewnia & Ploch, 2005). The diversity of roles enacted in a group contributes therefore to the richness of representations the group has with respect to the task.

Contrary to our expectations, the link between TB1 and teamwork quality is negative rather than positive (β=-.22, $t(81)$ =-2.06, p<.05). We have initially hypothesized that according to Belbin's balance claim, the fine adjustment of one role to another in a balanced group should lead to synergistic teamwork processes. Furthermore, as research on shared mental models argues, teamwork effective groups share in a balanced way both task as well as teamwork related knowledge (Cannon-Bowers & Salas, 2001). The negative association identified between TB1 and TWQ could be due to other factors that were not accounted for in the study. For example, the level of group conflict could have buffered the relation between group role balance and group complexity.

Nevertheless, the results pertaining to the positive influence of group role balance on group performance are rather isolated given that 1) only one group roles balance (TB1) positively predicts group cognitive complexity and 2) none of the group balance indicators actually predict group performance (perceived or objective).

The three thematic configurations also do not predict group objective performance, TWQ or GCC. One interesting result is the highly predictive power of action roles for perceived performance (β=0.22, $t(81)$=1.95, p<.05) but not actual performance (β=0.04, $t(81)$=0.44, p>.05). Groups with a high amount of action roles perceive themselves as performing well. However, this does not converge with the actual group performance. This can be explained on the one hand by the student's educational transition from high school to college and on the other hand by the focus of acting roles on having the task finished. The sample used in the current study is composed of first year students which experience the transition from high school to college. Given that they are confronted with different academic demands than they were used to in their previous education they often encounter difficulties in correctly assessing their tasks and appropriately setting their expectations (Perry et al., 2001; Haynes et al., 2006). This could explain the gap between the perceived performance of the students and their objective performance. In addition, groups with a high amount of active roles are characterized by the urgency to complete the task and implement the ideas developed without a thorough consideration and assessment of these ideas (Belbin, 1981). The combination of these two factors could explain why groups with a high amount of action roles have inaccurate perceptions of their performance.

3.7.3. The impact of the percentage of women on group performance

In order to test our last two hypotheses we ran two mediation models by using Preacher & Hays (2008) multiple mediation testing method with 1000 resamples in the bootstrapping procedure. In the first mediation model we have included percentage of women as an independent variable, objective group performance as the dependent variable and finally preference for teamworker role and teamwork quality as mediators. Group size was included as a control variable. Our results indicate that the direct effect of percentage of female on group performance is not significant as the 95% confidence interval (CI) includes 0, [CI -.0131, .0147] while the only indirect effect that is significant is the one in which the percentage of females impact on group performance through teamwork quality, CI [.0003, .0102]. The impact of the percentage of females on group performance through preference for the teamworker role is not significant, CI [-.0004, .0011]. In the second mediation model we have included percentage of women in the group as an independent variable, group cognitive complexity as the dependent variable and preference for the teamworker role together with teamwork quality as mediators. Group size was included as a control variable. The direct effect of percentage of females on group cognitive complexity is significant, CI [.0010, .0224], while the indirect effects are both not significant (for teamwork quality as a mediator, CI [-.0025, .0019], and for preference for teamworker role as mediator CI [-.0003, .0001]).

Our results bring only partial support for our third hypothesis. Teamwork quality mediates the impact of percentage of females on objective group performance but not on GCC. The more women in a group, the better the performance of the group is and this relation is explained by the quality of interactions experienced in the group. As indicated by Woolley et al. (2010) women tend to score higher than men in social sensitivity and therefore pay more attention to establishing and maintaining good interpersonal relations in groups (Woolley et al., 2010). However, our results indicate that the relation between percentage of women and GCC is not mediated by teamwork quality. The significant main effect could be explained by women's higher engagement with educational activities and their higher motivation to know, enhanced knowledge by exploration and setting up higher learning goals as compared to men (Vallerand et al., 1992).

Finally, our fourth hypothesis was not supported. Contrary to our expectations, the teamworker role preference does not mediate the link between the percentage of women and group performance or GCC. Women have a stronger preference for the teamworker role than men (Sommerville & Dalziel, 1998; Anderson & Sleep, 2004). We have found the same preference expressed also in our study t=2.09, p<.05, with women expressing a stronger preference for the teamworker role than men. However, this preference does not mediate the link between the percentage of women and group performance or group cognitive complexity. Group roles preferences, considered either at a group level (as group role balance) or at an individual level (e.g. preference for the teamworker role) does not appear to predict group performance. This comes in line with previous findings that also failed in identifying a clear link between group role balance and performance (Senior, 1997; Partignton & Harris, 1999; Water, Ahaus & Rozier, 2008; Jackson, 2002; Blenkinsop & Maddison, 2006).

3.7.4. Implications, limitations and directions for further research

Our study has important implications for group design literature as well as for collaborative learning literature. First, we put forward a comprehensive test of various group configurations with respect to group role preferences on various collaborative learning outcomes. Unfortunately, our tests did not support the claims advanced by group role theory, namely that balanced groups outperform unbalanced groups. This means that forming groups based on group members' preferences for group roles does not seem to deliver the promised goods. Second, we show that percentage of females in the group is conducive for collaborative learning effectiveness. We admit that using the percentage of women as a design principle when forming student groups in educational settings has limitations, yet a straightforward implication of our results is that educators should at least form mixed gender groups. This is in line with previous results showing that gender composition has positive influence on GCC (Curșeu, Schruijer & Boros, 2007) and group rationality (Curșeu, Jansen & Chappin, 2013). When gender composition is not a feature open to manipulation, educators could focus on short trainings to increase interpersonal awareness and social sensitivity or use normative interventions to influence directly the quality and nature of interpersonal interactions in collaborative learning groups (Curșeu & Schruijer, 2012).

Future research could explore possible explanatory mechanisms and our study points out that the quality of interpersonal interactions needs further attention in this respect. Finally, our study uses data collected from multiple sources (e.g., self-rated performance, real performance indicators and group cognitive complexity rated by external evaluators) and measures are separated in time, therefore the likely impact of common method bias is low. Given the strengths of our design, the substantial sample size and the variety of outcomes considered we can conclude that our findings are robust, yet future research is welcomed in replicating them in other organizational contexts.

Next to these strengths, our study has also certain limitations. First, group roles have been measured at the beginning of the workgroup as individual preferences for particular behavioral styles. However, we did not check whether these were indeed the roles assumed by the group members during their work. Although group roles are in principle considered to be individual preferences which are stable over time, it could be the case that due to dynamics unfolded in the group, members take other roles (e.g. secondary or tertiary roles) than the ones they have their first preference for. Second, our groups differed in size and this might be problematic especially when for the computation of group role balance that involves the presence in a high or very high level the presence of all nine roles. Although we tried to overcome this limit by controlling for group size in our analyses and by using different group balance indices, we do acknowledge this as a limitation of our study. Further studies could try to replicate these results in a more controlled setting in which all groups are composed with the same size and group roles preference stability is accounted for.

3.8. Conclusions

Belbin group roles are widely used in organizations, although the initially proposed claims have created many scientific controversy (Belbin, 1993;

Furnham, Steele & Pendleton, 1993). Our longitudinal study indicates that the claim of group balance as a predictor for teamwork quality and performance indicators does not hold in collaborative learning groups. One exception is group cognitive complexity, which appears to be predicted by group balance as computed by TB1, therefore with a group balance indicator that capture group role preferences as a configural property of groups instead of a sum of individual roles. Next to this, other indicators such as the percentage of females in the group appear to be highly predictive for teamwork quality and group cognitive complexity and thus should warrant further research.

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Chapter 4

MINORITY DISSENT AND LINK ACTIVATION AS PROCESSES FOSTERING TEAMWORK CREATIVITY[6]

4.1. Introduction

In order to become competitive, modern organizations pursue innovation and have to capitalize on individual and group creative performance. During the last decades, considerable research efforts have explored factors related to group creativity in the workplace (Hulsheger, Anderson & Salgado, 2009). To date however, group creativity has been conceptualized and studied mostly in terms of creative output, or how new and useful are the products or ideas generated by a group (Amabile, 1996; Zhou & Shalley, 2010) and measurements such as the quality and uniqueness of ideas produced by the groups have been employed as indicative for group creativity (Pearsall, Ellis & Evans, 2008; Shin & Zhou, 2007). Despite the crucial role attributed to teamwork processes (interdependent activities) and emergent states (West, 2002; Curșeu, 2010) by systemic models of group creativity, the extent to which groups change their processes to achieve better outcomes is still under examined. We would like to extend the view upon group creativity by switching the focus from creative outputs to creative processes, as greater flexibility required for creative outputs, imply that groups adapt, change and adjust their teamwork processes. Teamwork is the 'vehicle' through which group inputs are being transformed into outcomes (Marks, Mathieu & Zaccaro, 2001) and a creative (re-)configuration of this 'vehicle' can facilitate the quality of group outputs and performance. Our arguments build on the distinction between outcome creativity and teamwork creativity. While

[6] This chapter is based on: Meslec, N. & Curşeu, P.L., Meeus, M.T.H. Minority dissent and link activation as processes fostering teamwork creativity. Manuscript under review.

outcome creativity refers to the novelty and usefulness of the output produced at the end (e.g. urban design project), teamwork creativity reflects the novelty and usefulness of group processes (interdependent activities) employed by the group in order to reach its goal.

The purpose of the current study is to investigate two mechanisms (minority dissent and link activation) that are prone to influence teamwork creativity. Developed from the analogy/ metaphor field of research, the link activation mechanism illustrates a situation in which group members find similarities between two different apparently unrelated knowledge structures (Gentner, Bowdle, Wolff & Boronat, 2001). Knowledge structures are defined here as the ways in which people organize and relate concepts in a knowledge domain (Johnson-Laird, 1983; Davis, Curtis & Tschetter, 2003). When one of these knowledge structures belongs to the teamwork area/domain, then group members gain new insight in how to reconfigure their usual way of working together in order to achieve their (creative) goals. This reconfiguration is achieved by merging and aligning the existing teamwork knowledge structure with a different unrelated knowledge structure and this results in a new reconfiguration of teamwork process.

Minority dissent, as a second mechanism, reflects a social process in which a group member expresses an opinion/idea that differs from the rest of the group members (DeDreu & West, 2001). Not only will the group disagreement elicit a cognitive conflict that makes link activation more salient but also will trigger members' attempts to reduce the conflict and focus on finding new ways of working together. Therefore, given the cognitive nature of link activation, we argue that this mechanism changes the nature of the association between minority dissent and teamwork creativity.

Our study contributes to the group creativity literature in at least three major ways. First, it proposes a new take on group creativity which focuses on the teamwork processes rather than the group output. Second, it investigates a new mechanism through which teamwork creativity can be enhanced, namely link activation, a cognitive mechanism that facilitates knowledge sharing and integration. Third, not only it investigates a new process through which teamwork creativity can be enhanced but it also analyzes the interplay between link activation and minority dissent. As groups are socio-cognitive systems, it is likely that a social process such as minority dissent will interact with link activation, which is a cognitive process. In doing so, we explore the interplay between cognitive (link activation) and social processes (minority dissent) that have been largely overlooked in teamwork creativity research (Paletz & Schunn, 2010).

4.2. Theoretical background

4.2.1. Teamwork creativity

Organizational creativity has been conceptualized as the interaction among the creative person, the creative process and the creative product which is situated in an environment (Brown, 1989; Harrington, 1990; Woodman, Sawyer & Griffin, 1993). A large number of studies have been devoted to investigate the link between the creative person and the creative product (De Strobbeleir, Ashford & Buyens, 2011). In this regard, studies have been investigating how the creative output varies as a function of attributes such as individual creativity (Pirola-Merlo & Mann, 2004), personality attributes (Baer, Oldham, Jacobsohn & Hollingshead, 2008), cognitive styles (Basadur & Head, 2001) or configurations such as group diversity (Pearsall, Ellis & Evans, 2008; Curșeu, 2010). Creative output has been defined as the novelty and usefulness of an idea in a particular domain (Amabile, 1996) and mostly conceptualized and measured in terms of number and quality of ideas developed for a particular project (Pearsall, Ellis & Evans, 2008), the uniqueness and distinctiveness of a group product (Curșeu, 2010), or the newness, significance and usefulness of the ideas generated by the group (Shin & Zhou, 2007).

Meta-analytic evidence shows that the effect sizes of different group input variables on group creativity, are rather small (Hulsheger, Anderson & Salgado, 2009). One reason for this could be the fact that group creativity has been measured in more distal terms (e.g. creative output) rather than in more proximal terms, such as creativity as a process. Despite this, less attention has been devoted to creativity as a process: "Although we may acknowledge that a highly creative person (...) can generate a highly creative thought process (one that yields highly creative ideas), that person and that thought process are not relevant for study or for management unless the ideas are somehow expressed (…) Hence, it is only by reference to their products (…) that we can label persons as creative, and it is only by examination of the products of thought processes that we can label those processes as creative" (Amabile, 1996, p:3-4). Consequently, the focus on creativity as an output has been widely embraced in group research literature (Shin& Zhou, 2007; Hulsheger, Anderson & Salgado, 2009; Farh, Lee & Farh, 2010) with little consideration to creativity as a process. Although studies have been investigating processes which are prone to influence group creativity such as task conflict (Curșeu, 2010; Farh, Lee & Farh, 2010), or vision and task orientation (Hulsheger, Anderson & Salgado, 2009), they do not reflect creativity of the process but rather processes which influence the creative output.

In line with the distinction advanced by Marks, Mathieu & Zaccaro (2001), we propose that creativity can take two forms within groups: teamwork creativity and taskwork creativity. While taskwork creativity refers to the novelty and usefulness of the output produced at the end, teamwork creativity reflects the novelty and usefulness of group processes (interdependent activities) employed by the group in order to reach its goal. Group processes reflect '...members' interdependent acts that convert inputs to outcomes through cognitive, verbal, and behavioral activities in order to achieve collective goals' (Marks, Mathieu & Zaccaro, 2001, p. 357). Therefore, teamwork creativity includes the ability of group members to develop new and useful alternative courses of action and coordination acts in order to attain their goal. For instance, the change in teamwork structure after the unsuccessful Bay of Pigs invasion made the solving of Cuban Missile crises a successful case (outside experts were invited to share viewpoints, the group was divided into subgroups in order to avoid high cohesion) (Janis, 1972).

4.2.2. Minority dissent and teamwork creativity

Minority dissent describes a situation in which one group member or a minority of members express a position which contradicts the attitudes, opinions or ideas assumed by the group majority (DeDreu & West, 2001; Curşeu, Schruijer & Boroş, 2011). Both a positive and a negative connotation have been attached to minority dissent. On the one hand, groups usually seek for consensus and alignment of ideas and therefore members expressing different opinions than the majority are at risk to be ignored and marginalized (Stasser & Titus, 1985; Moscovici & Personnaz, 1991). Cognitive alignment becomes also functional given that it facilitates coordination and task performance (DeDreu & West, 2001). However, a too high alignment can lead to premature decision-making and a lack of consideration of available alternatives. Groupthink is one example in which desire for harmony overrides a realistic appraisal of alternatives (Janis, 1972). On the other hand, minority dissent can also have a positive impact upon group performance. Minority dissent is surprising and leads the group members to think why the minority thinks the way it does (Nemeth, 1986). Further on, it creates a tension which motivates group members to search for information and approach the situation at hand from different perspectives, fostering divergent thinking processes. Therefore, group members are more prone to identify new and creative solutions (Nemeth & Staw, 1989). Minority dissent has been associated with higher decision quality (Dooley and Fryxell ,1999; Schwenk, 1990; Schulz-Hardt, Brodbeck, Mojzisch, Kerschreiter and Frey, 2006), higher levels of cognitive complexity (Gruenfeld, Thomas-Hunt, & Kim, 1998; Curșeu, Schruijer & Boroş, 2011) and innovation (DeDreu & West, 2001; DeDreu, 2002;

Kenworthy, Hewstone, Levine, Martin & Willis, 2008). In sum recent research suggests that the relation between minority dissent and group creativity are contradictory. One way in which these results can be interpreted is by considering also the intensity of disagreement. Different amounts of disagreement might count in shaping the level of group creativity. While a low level of dissent might be insufficient for creating tension and divergent thinking (De Dreu, 2002; DeDreu & West, 2001), a too high level of disagreement which is maintained constantly in the group could lead to rejection of the group member in minority and difficulty in reaching a solution (Curșeu, Schruijer, & Boros, 2011). A similar concept - task conflict that reflects task related disagreements has been found to lead to more innovation when present in moderate amounts rather than high or low (DeDreu, 2006). Given the arguments presented above, we propose the following hypotheses:

H1. Minority dissent and teamwork creativity are curvilinearily related in such a way that minority dissent is beneficial for teamwork creativity up to a point and then it becomes negative.

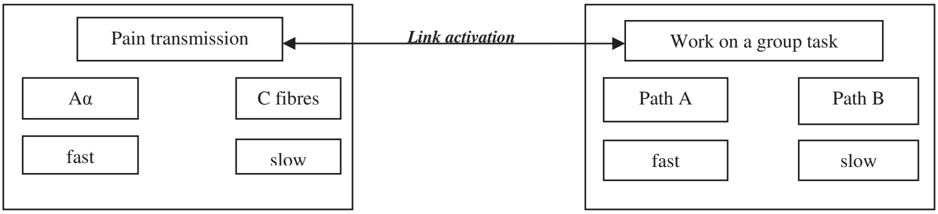
4.2.3. Link activation and teamwork creativity

Most of the groups employed in organizations to perform creative tasks are multidisciplinary. The reasoning behind is that diverse groups are coming with a large array of task related expertise and knowledge that can be assembled within the group and making it more creative (Hambrick & Mason, 1984; Wiersema & Bantel, 1992; Jackson, May & Whitney, 1995; McLeod, Lobel, & Cox, 1996; Watson, Kumar & Michaelsen, 1993). As stated by Milliken and Martins (1996), “a group that is diverse could be expected to have members who may have had significantly different experiences, and therefore, significantly different perspectives on key issues and problems” (p. 404). However, the large array of group knowledge not only can be useful for output creativity but for teamwork creativity as well. By looking into the task-related knowledge group members can arrive at different ways/perspectives/ideas on how to restructure their teamwork in a creative way. The impact on creativity increases as groups align highly distal knowledge structures, belonging to totally different domains (e.g. task domain and teamwork domain) as opposed to the same domain (e.g. task to task). Thus, the emerging challenge given the large knowledge pool in diverse groups is to find effective ways in which knowledge bridging can be achieved.

The process through which knowledge from one domain is aligned with knowledge from another domain of knowledge is called link activation. Teamwork knowledge is a temporally ordered type of knowledge, in which components such as mission analysis, goal setting or monitoring occur at different time points (Marks, Mathieu & Zaccaro, 2001). Therefore, the cognitive structure that best encapsulate this type of knowledge is a cognitive script. Scripts have been defined as cognitive schemata that store temporally ordered actions (Abelson, 1981; Abbot, Black & Smith, 1985; Nooteboom, 2000). The transfer from task-related knowledge structure towards group-related knowledge structures will involve scripted knowledge. Link activation takes place when the link between two components of two different scripts of two group members is being made explicit (e.g. A component from taskwork script S1 is the B component from teamwork script S2). This can be done with the use of analogies or metaphors between scripts coming from different knowledge domains. Imagine for instance a meeting of a medical group working on a difficult case. At a certain point one of the group members brings the following link activation example, between a teamwork domain and a medical domain: "I think that working on this task is like pain transmission" The two components of the activation belong to different areas. While pain transmission belongs to the medical domain, working on a group task belongs to the teamwork domain. After the link between the two concepts is being made explicit, the entire scripts related with pain transmission and teamwork will be simultaneously activated (Figure 4.1). This comes in line with the activation rule which stresses that one of the proprieties of knowledge structures is that once one of the components of a knowledge structure is being activated, the others are getting activated automatically. This rule has been proved to work in the case of script knowledge (Bower, Black, Turner, 1979; Graesser, Woll, Kowalski & Smith, 1980). Link activation between scripts will lead to the simultaneous activation of the whole scripts which will facilitate the transfer from task knowledge scripts towards teamwork scripts and creation of new teamwork knowledge. In our example, the most salient dimension of pain transmission is that it can be done in two different ways, that is via Aα fibres and via C fibres. Pain transmission to cortical areas via Aα fibres is faster relative to C fibres. These components belong to the pain transmission script. On the other hand working on a group task activates different ways in which the subtasks can be coordinated in order to achieve the final goal of the group. Via the structural alignment of the two scripts, new meanings are created with respect to the teamwork. In our example, one of the possible meanings could be that groups can accomplish subtasks in a faster or slower manner. This depends on the route they will choose to take while solving the task and not so much on the task in itself. To conclude, the link activation will reduce the ambiguity between two different scripts by 'highlighting the commonness of two different things' (Nonaka, 1994) and hence will lead the group towards the creation of new teamwork knowledge. Given the reasoning above, the following hypotheses emerges:

H2. Groups with link activation will be more creative in their teamwork than groups with no link activation.

Figure 4.1. *Link activation process between a doctor script and a teamwork script*



4.2.4. The interplay between minority dissent and link activation

Link activation is an information processing mechanism that influences the way in which individual knowledge structures are combined and integrated. Given its bridging nature, link activation will enforce information exchange from different knowledge domains with the purpose of aligning them in terms of similarities and creation of new knowledge relevant for the task solving. Minority dissent is a social process that also impacts on interpersonal interactions within groups. When one group member disagrees with the opinions expressed by the rest of the group the generated task conflict increases the potential for knowledge integration especially when the threat associated with minority dissent is diffused. Minority dissent has drawbacks as well, as it disturbs social harmony and leads to social exclusion and relationship conflicts ultimately hindering group performance. However, when the deviant leaves the group, these drawbacks are diminished and group members manage to benefit greatly from the divergent idea generation (Curșeu, Schruijer & Boros, 2011). By enforcing between-domains analogies, link activation induces a climate for cognitive conflict and therefore reduces the threat associated with minority dissent. In other words, when group members attempt to establish similarities and align distant knowledge domains as it is the case when link activation is present, dissent is more likely to be perceived as a natural process and as such its positive impact on knowledge integration substantially increased. Therefore, given the socio-cognitive nature of groups, we expect an interaction between link activation and minority dissent, with teamwork creativity varying across different configurations of this interaction (Hinsz, Tindale & Vollrath, 1997; Paletz & Schunn, 2010). When no link activation is present we expect that a moderate level of minority dissent is the most conductive to teamwork creativity (as stated in hypothesis 1). When the dissent is too high and constant, the group encounters difficulties in reaching a common solution, conflicts might erupt, which at the end lowers performance (Curșeu, Schruijer & Boros, 2011; Stasser & Titus, 1985; Moscovici & Personnaz, 1991). On the other hand, when the dissent is too low, no cognitive tension is being elicited and therefore the groups are less prone to exchange information and come up with creative solutions.

In the activation condition however, the pattern changes as a climate conducive for a knowledge-related conflict is induced. The link activation increases group members' awareness of interpersonal differences that eventually leads to better knowledge integration (unrelated concepts coming from different cognitive scripts could contribute to the task solving). Under these conditions, when group members value bridging among different individual contributions to the task, they are also more open to accept dissenters and their ideas. Therefore, the more dissent, the more information will be exchanged and the higher the chances for the group to elicit new and creative ideas. This comes in line with the empirical results showing that the threat diffusion associated with the departure of the dissenter increases the potential for knowledge integration in groups (Curșeu, Schruijer & Boros, 2011). In the link activation condition, a climate for knowledge conflict is being grounded (given the contradictory nature of the activation) and therefore the deviant opinions are being accepted without the need for minority to leave the group. In this context, the higher the dissent, the higher the information exchange among members and therefore the overall performance of the group. On the other hand, low dissent will lead to poor informational exchange and lower chances of group members to make sense of the activated links. Given the reasoning above, we hypothesize the following:

H3. In the link activation condition, the relation between minority dissent and teamwork creativity will change from an inverse U-shaped relationship into an increasing positive relationship.

4.3. Methodology

4.3.1. Sample

One hundred and twenty - three undergraduates at a large Dutch university participated in the experiment in exchange for 8 Euro. The participants were nested in 42 3-member groups, out of which 21 received the experimental manipulation (link activation). The sample was randomly selected from the campus and it was diverse with respect to composition: students came from 27 different specializations, including 22 different nationalities, being gender diverse (56.6% females).

4.3.2. Procedure & task

After filling in the consent form and the control variables questionnaires, participants were informed that they will participate in a group task for which they will be assigned to one of the three roles available: the biologist, the doctor or the psychologist. In the next step, they were asked to form groups of three people that included one biologist, one psychologist and one doctor. Group members did not know each other beforehand. Each participant received a short text that contained a task script belonging to one of the three domains: pain transmission (doctor), meerkat behaviour (biologist) and teamwork (psychologist). The teamwork script was developed based on the formalized structure of a typical student teamwork script derived from interviews conducted with students in the campus. All the scripts were of equal length, containing similar amounts of information, being organized in a temporary manner (see Appendix A). The understanding of the scripts was checked via 4 questions. The task story indicated that group members are on a holiday sitting on a river bank that has just been poisoned. On the other side of the river six birds needed to be saved. The task contained two parts. In the first part (task without constraints) each group had to describe on a sheet of paper the steps they need to take in order to cross the river and save the birds. They also had attached a drawing of the river. This task imposed no difficulties and the solving of the task was meant to induce a typical teamwork script. "The three of us would cross the river, then each one takes 2 ducks (task division), we will put them in a cage and then we will bring the birds back to the shelter (task integration)" (transcript from group 42). Task without constraints lasted totally 10 minutes and group members received beforehand a short description of the importance of the birds in order to create a sense of usefulness.

In the second part of the experiment, they had to solve the same task but with some additional constraints in crossing the river (Appendix C). The constraints were made in such a way that the solution was not possible without a creative change in the way they organize their teamwork. The task had a correct solution. Examples of constraints are: "the first log in the water cannot sustain more than two people. If three people step in, it will sink and all the people will get drawn & intoxicated" or "you cannot skip logs because each one of you can jump a maximum of 2.2 m. The distance is too high to jump from the river bank directly to the second log". In order to solve the task (to save the 6 birds sitting on the other side of the river) groups had to use 1) double synchronization (two people had to jump at the same time on the first log) and triple synchronization (all the three people had to jump at the same time, 2 forward but on different logs and 1 backwards) or 2) a double synchronization combined with a following of different paths (jumping on different parts of the logs could bring them to the target faster or slower). The two solutions mentioned involve a different teamwork script than the formalized student one. It involves a simultaneous coordinated work of two or even three group members as opposed to the regular student script where task is being divided at the beginning, group members continuing to work independently until the end, when they integrate all the separate parts. The second part of the experimental task lasted totally 15 minutes. At the end, group members had to fill in a short questionnaire containing the minority dissent scale and perceived creativity after which they have been debriefed, rewarded and thanked for their participation.

4.3.3. Manipulation

Half of the groups involved in the study were induced a link activation manipulation between a teamwork script and one of the other two scripts (biologist and the doctor script). Manipulation came under the form of a message belonging to the forest guardian. Presented as cues useful in solving the task, groups received two different activations, one from the biologist to the psychologist knowledge areas and one from the doctor to the psychologist knowledge areas.

The first activation (A1) was *working on your own for a subtask is like pain transmission* (activation between teamwork script and doctor script) while the second activation (A2) was *working on your own for a subtask is like hiding behavior of meerkats when predators approach* (activation between teamwork script and biologist script). Both terms in the analogy were present in the scripts they received at the beginning, scripts which they had at their disposal along the task. The two activations resemble the structure of a metaphor and therefore each activation line has two components: a target (of which you want to say something, in this case *working on your own for a group subtask*) and a base (from which you want to say something, in this case *pain transmission* and *meerkat warning bark*) (Gentner, Bowdle, Wolff & Boronat, 2002). When metaphors are new (and this is the case here), people align the literal senses of both components, the process at hand being a comparison (Bowdle & Gentner, 2005). Therefore, while reading the first link activation line, group members activate the information from the two scripts referring to the two terms belonging to A1 and structurally align the information related to *working on your own for a group* *subtask* with the information related to *pain transmission.* Via this structural alignment, groups import knowledge from a totally different domain (medicine) and transfer it to the teamwork domain.

While processing the link activation, group members can reach several different understandings on how teamwork can occur and these understandings can lead to the employment of an efficient way of teamwork which equals the solving of the bird task. For example, the first activation line is *working on your own for a subtask is like pain transmission.* This can lead to the understanding that subtasks can be accomplished faster or slower, just as pain transmission can be made via a fast route (Aα fibers) or a slow route (C fibers). This can trigger further the idea that the group members can cross the river on different paths which will bring them faster or slower at the desired location. This idea is highly relevant for finding one of the solutions for the task. The same process is valid for the second activation. After receiving the activations, groups had 20 minutes to come up with a solution for the bird task and write it down in steps.

4.3.4. Measurements

Because we hypothesized a non-linear association between minority dissent and teamwork creativity, minority dissent was not manipulated but measured with a 5-items questionnaire developed by one of the authors. Respondents indicated their agreement with each item on a scale of 1 (*strongly disagree*) to 5 (*strongly agree*). One item example is: "One member consistently challenged the views expressed by the other group members". Reliability was calculated at α=.73. Next to the minority dissent scale, perceived creativity has been measured with a 4-items scale. Starting from existing items we developed the creativity scale in such a way that both novelty and usefulness as core dimensions of creativity are reflected. One item example for novelty is: "Our group came up with original and inspiring new ideas" and for usefulness is "The solutions proposed by our group can be used to solve similar problems". Reliability of the scale was calculated at α=.80. Given that the correct solution requires computational skills in terms of time and distance, the numeracy test was used as the first control variable. The test refers to group members' ability to understand and use numeric information. Participants had to choose the correct solution for each of the eight items. One item example is "If a person runs with a speed of 30 km/h, how many km would he be running in 150 min?" (Lipkus, Samsa & River, 2005). Reliability of the scale was calculated at α=.70. The solution for the task could have also been influenced by individual creativity. Therefore, the Alternate Uses Task was used in order to measure group member's divergent thinking (Wallach & Kogan, 1965). Participants were asked to list as many possible uses for three common items: a newspaper, a paperclip and a shoe. Creativity was rated while considering the amount of new uses in a predefined time (5 minutes).

Teamwork creativity coding. Teamwork creativity was defined as the novelty and usefulness of group processes (interdependent activities) employed by the group in order to reach its goal. Accordingly, groups' solutions for the bird task were assessed. In order to solve the task, group members had to reconfigure their usual teamwork script and organize themselves in a totally new way. A standard student teamwork script includes an initial division of the task followed by individual work on subtasks with integration at the end. The task was designed in such a manner that solving it would require different rearrangements of teamwork with components such as double or triple (simultaneous) synchronization. Therefore, success in solving the task is an indicator for teamwork creativity. The solutions (which were written down in steps) were coded on three dimensions. The first dimension coded was novelty and indicated how much the teamwork indicated in the solution differs from a usual student teamwork script. Components such as synchronizations and creative manipulations of the environment in conjunction with teamwork have been rated as novel. The second dimension coded was usefulness and it indicated how many birds are saved at the end. The second dimension indicates whether the novel teamwork employed is indeed helpful for goal achievement. Finally, the third dimension coded was teamwork richness and it indicated how much groups used teamwork as a mean to solve the task as opposed to other possible alternatives (e.g. call an external party to help). The third dimension was meant to filter out those solutions which did not involve teamwork. A composite score was computed while adding the three individual scores for the three dimensions (see Appendix B).

4.4. Results

Descriptive statistics and correlations between the variables are shown in Table 4.1. Most participants proved a good understanding of the scripts, the means for the three script checks varying from 0.86 to 0.96, where 1 reflects a correct understanding of the texts.

Table 4.1. *Means, standard deviations, and correlations between variables*

13	M	SD	1	2	3	4	5
1. Group mean numeracy	.83	.12					
2. Group mean individual creativity	4.14	1.12	-.21				
3. Minority dissent	2.39	.52	.18	.37**			
4. Link activation	.50	.50	-.03	-.07	-.01		
5. Teamwork Creativity (objective)	1.21	.51	00	.01	-.15	00	
6. Perceived Teamwork Creativity	3.62	.59	-.03	.33**	.20	-0.03	.13

Note. N=42 groups; *p<.10**p<.05***p<.01.

No significant differences were identified between the two experimental conditions with respect to individual creativity (t=.44, p=.65, 95% CI [-0.84, 0.53]) or numerical abilities (t=.24, p=.8, 95% CI [0, 0.07]). Hypothesis 1 suggested that minority dissent has an inverted U shaped relationship with teamwork creativity. As shown in Table 4.2 (Model 2), the quadratic term of minority dissent is marginally significant (β=-.33, p=0.06, 95% CI [-0.97, 0]).

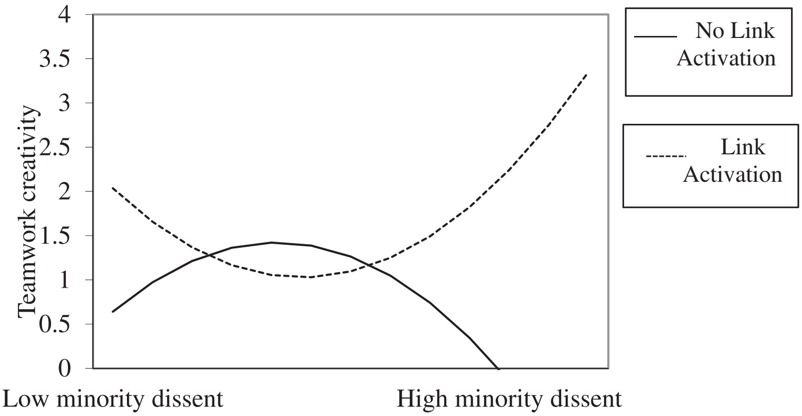
Table 4.2. *The Interaction Effect between Minority Dissent and Link Activation on Objective Teamwork Creativity*

Predictor	*B*	*SE*	β	*t*	R^2	*F-change*
Model 1					.02	.42
Minority Dissent	-.15	.16	-.15	-.91		
Link Activation	0	.08	.01	.08		
Model 2					.11	3.7*
Minority Dissent	-.04	.17	-.04	-.25		
Link Activation	-.02	.08	-.03	-.23		
Minority Dissent^2	-.47	.24	-.33	-1.93*		
Model 3					.12	.15
Minority Dissent	-.05	.17	-.05	-.32		
Link Activation	-.02	.08	-.04	-.24		
Minority Dissent^2	-.48	.25	-.33	-1.93*		
Link Activation x Minority Dissent	-.06	.16	-.06	-.38		
Model 4					.24	5.57**
Minority Dissent	-.11	.16	-.11	-.68		
Link Activation	-.18	.10	-.36	-1.76*		
Minority Dissent^2	-.01	.30	0	-.04		
Link Activation x Minority Dissent	-.19	.16	-.19	-1.15		
Link Activation x Minority Dissent^2	.72	.30	.62	2.36**		

Note: *p<.10**p<.05.

Further on, as indicated in Figure 4. 2., the shape of the relation is an inverted U-shape, which lends support to hypothesis 1. In hypothesis 2 we predicted that in the link activation condition groups will be more creative in their teamwork than in the non-link activation condition. The coefficients of an independent sample T-test indicated no difference between the two experimental conditions (*t*= -.03, *p*=.97, 95% CI [-0.33, 0.32]). The second hypothesis is not supported. In hypothesis 3 we predicted that in the link activation condition, the impact of minority dissent upon teamwork creativity will change in a U-shaped relationship. As shown in Table 4.2., the interaction term between minority dissent quadratic and link activation is significant (*β*=.62, *p*=0.02, 95% CI [0.1, 1.35]). As it can be seen in Figure 4.2., the relation is increasing positive, with the highest creativity when minority dissent is high. Hence, the third hypothesis is supported. In order to cross- check the stability of our results we have run a similar regression analysis, this time with perceived creativity as the dependent variable.

Figure 4.2. *Curvilinear interaction of minority dissent with link activation on teamwork creativity*



Our results (Table 4.3.) indicate a similar trend, with the interaction term between minority dissent quadratic and link activation being significant (β=.71, p=0.03, 95% CI [0.07, 1.80]). As indicated in Figure 4.3., the relation is also U-shaped, with an increasing positive trend.

Table 4.3. *The interaction effect between minority dissent and link activation on perceived teamwork creativity*

Predictor	*b*	*SE*	β	*t*	R^2	*F-change*
Model 1					0.04	0.73
Minority Dissent	.23	.19	.20	1.16		
Link Activation	-.03	.10	-.06	-.36		
Model 2					0.05	0.32
Minority Dissent	.27	.21	.24	1.28		
Link Activation	-.05	.10	-.08	-.48		
Minority Dissent^2	-.17	.31	-.11	-.57		
Model 3					0.05	0.15
Minority Dissent	.25	.22	.21	1.10		
Link Activation	-.04	.11	-.08	-.43		
Minority Dissent^2	-.18	.31	-.11	-.57		
Link Activation x Minority Dissent	-.08	.21	-.07	-.39		
Model 4					0.19	4.93**
Minority Dissent	.10	.22	.09	.47		
Link Activation	-.24	.13	-.41	-1.80*		
Minority Dissent^2	.48	.42	.30	1.15		
Link Activation x Minority Dissent	-.30	.22	-.26	-1.35**		
Link Activation x Minority Dissent^2	.94	.42	.71	2.22**		

*Note:**p<.10**p<.05.

Figure 4.3. *Curvilinear interaction of minority dissent with link activation on perceived creativity*

4.5. Discussions

The purpose of the study was to investigate two mechanisms relevant for teamwork creativity: minority dissent and link activation. In support to our hypotheses we found that moderate levels of minority dissent are the most beneficial for teamwork creativity. However, when the bridge between two different areas of knowledge is being made explicit, the pattern changes, with high levels of dissent being the most beneficial for teamwork creativity (both objective and perceived).

4.5.1. Theoretical implications

The current study contributes to the understanding of group creativity field in several different ways. First, it considers a different dimension of group creativity, namely teamwork creativity, whereas the large majority of creativity research focused on creativity in terms of output. Teamwork is the process through which group members orchestrate their interdependent activities in order to reach their collective goals (Marks, Mathieu & Zaccaro, 2001). When the regular order of teamwork is disrupted and the interdependent activities are reorganized in a creative way, group members benefit from gaining new insights/perspectives on their task. Furthermore our study contributes to group creativity field by developing an experimental task through which teamwork creativity can be measured. The bird-saving task is constructed in such a way that groups can solve it only if they manage to rearrange their typical teamwork script by integrating the specific knowledge structures of their members. The solution quality of the task (although an output) becomes a direct indicator for teamwork creativity. The focus changes therefore from creativity as an output as it has been conceptualized and measured previously (e.g. the novelty and usefulness of a product) to the creativity of the process (teamwork creativity), given that the solution quality is a direct indicator of the novelty and usefulness of group processes (interdependent activities) employed by the group in order to reach its goal.

A second contribution of the study consists in analysing the impact of two mechanisms upon teamwork creativity. Our findings reveal that the non-linear association between minority dissent and teamwork creativity is moderated by link activation in such a way that for groups without link activation the association between minority dissent and teamwork creativity has an inverted U shape, while for groups with link activation the association is increasing positive. The results illustrating the interaction between minority dissent and link activation are in line with the systemic perspective which underlines the socio-cognitive nature of groups (Hinsz, Tindale & Vollrath, 1997; Hutchins, 1995; Paletz & Schunn, 2010). The link activation mechanism between different scripts belonging to different group members will hardly sustain itself given that group members navigate in different knowledge representational spaces belonging to their backgrounds without a shared/common representation. A social process such as minority dissent boosts the information exchange (cognitive conflict) and increase group's chances to elicit new and creative ideas. However, the amount of social process experienced in the group will determine whether the group succeeds in rearranging its typical script in a creative manner. When link activation is present, the more dissent will lead to higher teamwork creativity. A constantly disagreeing member will trigger a high exchange of information from group members' background scripts, facilitating the structural alignment of A1 and A2 components and enhancing further on the creativity of the teamwork solutions. In the context of activation, the dissent will be socially accepted, given the already conflictual nature of knowledge activated. This result indicates the potential benefits of encouraging dissent in groups, especially when knowledge from different areas are to be exchanged and bridged. In the non-link activation condition, minority dissent does not have the same value. Given that there is no potential to bridge between knowledge areas, group members will focus on finding a way of solving the task without necessarily considering their own background knowledge. In this situation a moderate level of dissent is the most beneficial. Too high dissent will lead to conflicts and a lack of integration while too low dissent will lead to insufficient exchange of information with respect to the task. Although moderate levels of minority dissent are the most predictive for objective teamwork creativity, this result was not replicated for perceived creativity. One explanation could be that groups might perceive themselves as being less creative when they experience dissent and cognitive conflicts inside the group.

4.5.2. Limitations and directions for future research

Although our study has notable strengths, such as the strict manipulation of cognitive mechanisms in controlled experimental settings, we acknowledge certain limitations. First, we would like to acknowledge the limits of the ad-hoc groups used in the study. Group members worked with each other for a short period of time in order to achieve a short-term goal. The interaction inside groups is prone to develop differently if group members have to work on several projects on a larger period of time. Further research could approach this issue by investigating knowledge bridging mechanisms inside groups already operating in organizations. Appealing for further research would be studying the ways in which the process of link activation naturally occurs in groups. As in the current study it was only artificially induced, the lack of effect upon teamwork creativity can be also a result of that. The current study also assumes that teamwork creativity is linked with creative outputs. The task was designed in such a way that the output (saving the birds) cannot be reached without a creative reconfiguration of the teamwork. However, interesting would be to test if this assumption holds, thus if creative reconfigurations of teamwork lead indeed to more creative outputs. Finally, the current study only focuses on the bridging between task-related knowledge and group-related knowledge. In order to broaden our understanding on how bridging mechanisms work inside groups, further studies could approach different types of links, such as those directed from task-to-task or teamwork-to-teamwork knowledge.

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Chapter 5

WHEN DO GROUPS PERFORM BETTER THAN THEIR BEST INDIVIDUAL MEMBER? PRESCRIBED DECISION RULES FOR GROUP COGNITIVE COMPETENCES[7]

5.1. Introduction

Organizations extensively use groups to perform a variety of cognitive tasks (Tannenbaum, Mathieu, Salas & Cohen, 2012) and collective decisions are essential for organizational performance (Forbes & Milliken, 1999). Reliance on groups in social life is built on a strong assumption, namely that the array of information exchanged, explored and integrated in groups enhances decision quality relative to individual choices (Hinsz, 1990; Vollrath, Sheppard, Hinsz & Davis, 1989). Similarly, other species organize and work in collectives in order to enhance their survival chances. For example, homing and migrating birds collectively decide on communal routes that maximize their chances of survival and successful arrival to their destination and swarms of bees and ants collectively choose new nest sites on which their survival depends (Conradt &List, 2009; Sasaki & Pratt, 2012; Edwards & Pratt, 2009). Social interactions unfolding in such collectives shape the emergence of collective choices that transcend a simple aggregation of individual preferences or competencies (Curșeu & Schruijer, 2012; Krause, Ruxton & Krause, 2010; Berdahl et al., 2013).

Although groups have the potential to become superior (as interacting collectives) to standalone individuals or simple aggregation of individual actions or competencies, this (emergent) potential is not always realized in real-life situations. Studies stemming from the group synergy literature illustrate not only

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that groups do not manage to achieve strong cognitive synergy (perform better than their best individual member - Laughlin, Gonzalez & Sommer, 2003; Fischer, 1981; Meslec & Curșeu, 2013) but sometimes they even have difficulties to achieve weak cognitive synergy (they perform worse than the average individual performance in the group - Buehler, Messervey & Griffin, 2005; Hinsz, Tindale & Nagao, 2008). Obviously, group synergy is a group emergent phenomenon that is rather difficult to achieve in interacting groups (Curșeu, Jansen & Chappin, 2013). Therefore, understanding the way in which individual choices and competencies are combined and coordinated through social interactions in order to generate superior collective outcomes is of key importance to understanding the emergence of collective cognitive competencies (Woolley, Chabris, Pentland, Hashmi & Malone, 2010; Curșeu, Jansen & Chappin, 2013).

This paper investigates experimentally how inducement and the nature of decision rules affect group synergy. In line with Kurt Lewin's statement that "you cannot understand a system until you try to change it" (Schein, 1996) and in order to better understand how groups work in their attempt to achieve strong cognitive synergy we test the effects of direct versus analogical way of inducing two decision rules, namely the collaborative and identify the best decision rule. One way in which groups can increase the quality of their collective choices is to identify their best performing individual and improve its performance. Simulation studies indicate the superiority of the expert rule, that requires the identification of the expert member of the group in comparison to the aggregate rule that requires the ability to pool information from multiple individuals in the group, and call for empirical studies testing this particular prediction in real life groups (Katsikopoulos & King, 2010). However, the literature to date only tested the effects of decision rules that were directly induced and little interest is shown to explore the role of decision rules that are autonomously developed by groups. As groups in modern organizations are increasingly autonomous (Kirkman & Rosen, 1999) and often copy other successful groups (Kouchaki et al., 2012) or individuals in their environment (Toelch et al., 2010), it becomes highly relevant to contrast the directly induced decision rules with the rules developed by groups through analogy.

5.2. Group cognitive synergy and decision rules

Collective cognitive competencies (e.g., collective intelligence, group rationality) refer to the ability of groups to accomplish collectively things that cannot be achieved by the aggregation of individual (cognitive) efforts. Following Larson (2007) we argue that collective cognitive competencies reflect groups' synergetic cognitive processes. Group synergy is achieved when the collective performance of interacting individuals becomes higher than the performance achieved by a simple combination of standalone group member efforts (Larson, 2007). Two levels of group synergy are discerned in our study: 1) weak cognitive synergy when collective cognitive performance is better than the average performance of group members, and 2) strong cognitive synergy, when collective performance exceeds the performance of the best performing individual in the group (Larson, 2007, p. 415).

Although previous research shows how social interaction can foster group synergy as an emergent phenomenon (Curșeu, Jansen & Chappin, 2013), groups often have difficulties in becoming better than their best individual member (Laughlin, Gonzalez & Sommer, 2003; Meslec & Curșeu, 2013; Sniezek, 1990) or the average performance of the group members (Buehler, Messervey & Griffin, 2005; Hinsz, Tindale & Nagao, 2008; Argote, Devadas, & Melone, 1990). A number of decision rules have been developed in order to guide group interactions and minimize process losses (e.g., unequal participation, loafing) associated with low performance (Reagan-Cirinciore, 1994). Decision rules are prescribed norms that guide the interaction of the group members and influence the way in which information is communicated and integrated in the group. The purpose of this first study is to contrast two such decision rules on the one hand and their way of inducement on the other hand in order to explore which rule (collaborative or identify-the-best) induced in which way (direct or analogical) is the most beneficial for group cognitive synergy.

5.2.1. Collaborative vs. identify-the-best decision rules

The collaborative decision making rule has received considerable attention in both human and animal group research (Curşeu et al. 2013, Reagan-Cirincione 1994; Conradt & Roper, 2005; Sumpter et al. 2008). The collaborative decision rule encourages opinion sharing and equal participation of all group members during deliberations. It turns out that external facilitators that encourage the participation of all group members in the task contribute to group decisions that exceed the decision of the best performing member in the group (Reagan-Cirincione, 1994). Given that group members are provided with the opportunity to discuss and contribute with their unique knowledge and expertise, collaborative decision rules are conducive to knowledge integration and foster decision quality. Curşeu, Janssen and Chappin (2013) reported that although on average, groups did not manage to achieve strong synergy, groups that follow a collaborative decision rule managed to get closer to the rationality of their most rational group member than groups following a consultative rule. Therefore, although the collaborative rule increases the information processing efforts in groups, it also has shortcomings: (1) in absolute terms has not yet been proved to lead to strong cognitive synergy, and (2) it comes with costs in terms of time and cognitive resources that need to be invested in the group decision.

This study pursues to address these two shortcomings by using heuristics inspired from the ecological rationality view. Heuristics are decision-making strategies that simplify the decision situation and assist decision-makers make frugal and accurate decisions using rather limited information (Gigerenzer & Gaissmaier, 2011; Toelch et al., 2009, 2010). The highlight of ecological rationality literature is the less-is-more effect, which illustrates an inverse U-shaped relation between the level of decision accuracy and the amount of information considered. In line with ecological rationality, we argue that a decision rule such as identify-the-best is particularly relevant to cognitive synergy, given that the core of strong synergy lies in groups outperforming its best individual member.

We test the use of a particular heuristic decision rule (identify-the-best), which decreases the information processing demands on groups, and as a consequence fosters the emergence of strong cognitive synergy. Identify-the-best heuristic requires group members to identify the most capable member in the group and to improve his/her performance. This comes close to the take-the-best decision-making heuristic because group members need to search in the group the person with the highest decision accuracy, stop the search when the person is found and adopt that person's decision as the group's decision which is considered further for improvement. Take-the-best heuristic has been proved to be an effective strategy in predicting accuracy as compared to other more complex decision strategies (Czerlinski et al., 1999; Gigerenzer& Gaissmaier, 2011).

Given that the identify-the-best rule relies on 1) a simple adaptive decision-making heuristic which does not require groups to draw on a large pool of information when establishing their group decision rule and deciding as a group, and 2) is directly conducive to cognitive synergy we expect it to yield superior outcomes in generating strong cognitive synergy relative to the collaborative decision rule. A simulation study indicates in this direction that the expert choice rule (identification of informed individuals) is actually a better decision rule than the aggregate rule (ability to pool information from multiple individuals) in single-shot decisions (Katsikopoulos & King, 2010). The result remains stable even when the probability of groups to fail identifying the best performing group member is accounted for. Therefore, we expect the identify-the-best decision rule to be superior to the collaborative rule for groups in reaching cognitive synergy.

5.2.2. Direct vs. analogical inducement

In this study we also manipulate the way in which decision rules are induced. Recent experimental research only explored the effects of directly induced decision rules (Curșeu & Schruijer, 2012; Curșeu et al., 2013). Self-managing groups are information processing systems that need to continuously adapt to their environments and they often copy successful work-related practices and processes used by other successful groups (Kouchaki et al., 2012; Toelch et al., 2010). Therefore, decision rules with the potential to foster strong synergy may stem from analogies made with successful groups in the environment. In real organizational groups, normative frameworks guiding interpersonal interactions (e.g., decision rules) can be directly induced through top-down managerial interventions (Malhorta et al., 2001). Nevertheless, in self-managed groups these normative frameworks are often generated autonomously by group members themselves (Kirkman & Rosen, 1999).

In the direct inducement condition, group members are directly instructed which rule is to be followed while in the analogical condition groups have to find their own decision rule while using relevant examples of successful decisions made by individuals or groups. Thus, via analogy with a successful group positioned in a similar decision situation, groups need to construct a viable decision rule for their own group. The analogical manipulation is in fact a form of the imitate-the-successful heuristic. Imitate the successful is a social heuristic that is successfully used not only in humans (Gigerenzer & Gaissmaier, 2011; Haunschild & Miner, 1997) but also animals (Schuster et al., 2006). Archer fish for instance is a species that learns a difficult insect hunting technique mainly from extensive observation of the skilled fish who already acquired the technique instead of extensive training or trial-and-error attempts (Schuster et al. 2006).

Given the combination of manipulations (type of rule x way of inducement) we developed two sets of predictions. On the one hand, we expect groups which follow identify-the-best rule via analogy (IBA) to be superior to groups which follow the collaboration rule via analogy (CA). In the IBA condition groups have to establish their own decision rule while imitating a successful case and the successful case in this particular condition employs a decision rule in which the most capable member needs to be identified and his/her performance improved before becoming a part of the group's solution. IBA is thus a condition which reflects a combination of two heuristics: imitate-the-successful and identify-the-best which is particularly adaptive for groups that pursue cognitive synergy. Given that CA involves imitating a decision rule which draws on a large pool of information and which it is not particularly adaptive for the case of group cognitive synergy, we expect it to yield results which are inferior to the IBA condition. On the other hand, we expect the direct inducement to be superior to the analogical one, given that groups are explicitly instructed to use the decision rule offered to them and do not need to derive it analogically, which involves an extra step in the group's process of establishing a decision-making rule.

In summary, we expect that: 1) the level of the group synergy in collaborative direct condition (CD) exceeds the group synergy in the collaborative analogical (CA) condition, and 2) that the level of group synergy in the identify-the-best direct (IBD) condition exceeds the level of group synergy in the IBA condition.

5.3. Ethics statement

We report the results of two experimental studies, one conducted in Romania and one in The Netherlands. The studies were designed as integrated part of curricular activities. Participants were invited to participate in a group decision exercise as part of a workshop on individual and group decision making (part of an Organizational Behavior course in a Dutch university and part of a Social Psychology course in a Romanian university). Because the exercise is part of curricular activities, it involves no foreseeable risk for the participants. Given that (1) the experiment was conducted as part of class related activities and no risks greater than the risk usually associated with class attendance in higher education programs were involved and (2) according to the Dutch and Romanian ethical guidelines, studies involving filling out short questionnaires that do not involve highly sensitive or embarrassing issues are exempted from ethical committee approval, no ethical committee consent was required for this study. Participants were nevertheless informed verbally and in writing that their questionnaires filled out during this particular workshop will be (anonymous) used for scientific research. All students could access a message placed in the electronic communication system and before the exercise all participants were verbally informed that the results will be used for scientific research and asked for their verbal consent. Moreover, participants were informed that if they experience distress associated with their participation in the exercise, they should notify the teachers immediately. Finally, all participants were debriefed after the exercise as part of the reflection on how individual choice leads to group decision quality (the topic of the interactive lecture).

5.4. Methods Study 1

5.4.1. Participants and procedure

One-hundred-forty-six students enrolled in an introductory course at a Romanian University (Age_{mean}=20.59, 130 females) participated in the study. The students were informed that they will participate in a decision-making exercise as part of their collaborative learning experience and were debriefed at the end of the exercise. The Winter Survival exercise (Johnson & Johnson, 1987; Rogelberg, Barnes-Farrell & Lowe, 1992) is a disjunctive decision-making task that has a correct solution. In the task, the participants had to imagine that they have just survived the crash of a small plane in the north of Canada, in extreme cold conditions. Having 12 items at their disposal they had to decide which ones are the most important for their survival. Therefore, the task is to rank-order the 12 items from lowest to highest importance for their survival. In a first step, group members had to rate the objects individually. After performing the exercise individually, the students have been assigned to 48 groups (average group size=3.04) and were asked to perform the same task in groups. The task order (administered first to individuals and then to groups) comes in line with the conceptual framework of cognitive synergy which attempts to capture the role of interpersonal interactions on the emergence of group cognition. Previous studies investigating the concept of group cognitive synergy have used a similar task succession (Hall & Watson, 1970; Curșeu et al., 2013; Meslec & Curșeu, 2013).

Finally, at the end of the exercise, participants compared their individual performance scores with the group scores and reflected upon the impact of decision rules upon group dynamics. Of particular interest for discussions were groups that managed to become better than the best performing group member and groups that failed. Social and organizational implications of group decision making have also been discussed as part of the debriefing.

5.4.2. Manipulations

In the current study we crossed two manipulations (decision rule and type of inducement), each with two possible conditions. We have used a between-group design. The 48 groups have been allocated to one of the four possible conditions: 12 groups to identify-the-best direct (IBD) condition, 11 groups to collaborative direct (CD) condition, 13 groups to identify-the-best analogical (IBA) condition and 12 groups to the collaborative analogical (CA) condition. In the direct inducement conditions, groups have been asked to employ either the method of group collaboration (CD) or the decision rule of identifying the best performing group member (IBD). The method of group collaboration (Hall & Watson, 1970) involves that ranking for each of the 12 survival items must be agreed upon by each group member before it becomes a part of the group decision. The decision rule of identifying the best performing group member involves that group members must strive to identify who is the most capable member in the group and then try to improve his/her performance. For the first two conditions (IBD and CD), the two decision rules have been directly communicated to the groups. For the last two conditions (IBA and CA) group members had to follow the same rules of collaboration and identifying-the-best, but this time the inducement has been made via analogical scenarios. In condition IBA, before solving the task groups had to read for 5 minutes a scenario that described the behavior of ant colonies in food searching. The scenario contained an example in which the ants were explicitly identifying the most successful ant in the colony (the ant who managed to find a food source) and working on improving its performance (accentuating the pheromone trail on the path leading to the food source so that even more ants to be able to identify the path to food) (follow- the- best heuristic) (Biseau & Pasteels, 1994). While drawing on the ants' scenario, groups were asked to discuss for 15 minutes and elaborate their own group decision rule which they can further on use in the Winter Survival task (imitate-the-successful heuristic). Thus in the IBA condition we have induced the same decision rule of identifying-the-best in an analogical rather than a direct way. We have applied the same logic to the CA condition, in which we induced the idea of collaboration via a scenario of bees which were deciding for choosing a new nest. The scenario was designed in such a way that it suggested the idea of collaboration as being crucial for the success of the bee colony (Sumpter et al., 2008; Conradt & Roper, 2005). After reading the bees' scenario, groups were asked to discuss for 15 minutes and elaborate their own successful group decision rule which they can further use for the task.

5.4.3. Measurements

Performance scores (as accuracy measures) were obtained by comparing individual and group rankings with the expert rankings. The absolute differences between individual and group rankings on one hand and expert rankings on the other hand have been summed up to obtain a performance indicator for both individuals and groups. For the sake of clarity we used recoded raw performance scores in the analyses given that high scores were indicative of low performance and low scores of high performance (Meslec & Curșeu, 2013). In line with Larson (2007), weak cognitive synergy has been computed by subtracting the mean of individual scores in the group from the group score. Positive scores of weak cognitive synergy reflect thus that the group managed to perform better than the average of its group members while negative scores indicate the group actually performed worse than the average. Strong cognitive synergy has been computed by subtracting the score of the best performing member of the group from the group performance score. Positive scores indicate that the groups managed to outperform their best individual member and negative scores indicate that the groups did not manage to become better than their best individual member.

Table 5.1. *Correlation table with descriptive statistics Study 1 (N=48)*

	Mean	*SD*	1	2	3	4
1.Weak cognitive synergy	-0.21	7.03				
2.Strong cognitive synergy	-5.50	7.21	0.91***			
3. Gender variety	0.13	0.26	-0.03	-0.15		
4. Individual maxim score	21.54	5.25	0.13	-0.08	0.06	
5. Group size	3.04	0.28	-0.04	-0.19	-0.07	0.12

Note: ***<.01

5.5. Results Study 1

In order to test our hypotheses we ran a GLM multivariate analysis with weak and strong cognitive synergy as dependent variables. Given that in larger groups the levels of participation and thus knowledge integration are lower we have added group size as a covariate in the analysis. Next to this, the maximum score in the group and gender variety have also been added as covariates. The use of maximum score is an attempt to control for lower likelihood of achieving strong synergy when the best performer scores are very high (Meslec & Curșeu, 2013; Curșeu, Jansen & Chappin, 2013). Group gender composition has been found to be an important predictor of emergent collective cognitive competencies (Curșeu, Jansen & Chappin, 2013; Woolley et al., 2010). Therefore we have included gender diversity as a covariate. Gender diversity has been computed with the Teachman's index (Harrison & Klein, 2007; Curșeu et al., 2007). Means, standard deviations and correlations of the variables included in the study are presented in Table 5.1.

Table 5.2. *Descriptive statistics manipulations Study 1*

	Mean		SD		N
	WS	SS	WS	SS	WS/SS
Identify-the-best direct	-2.25	-6.16	6.12	5.93	12
Collaboration direct	-0.98	-7.81	8.72	8.68	11
Identify-the-best analogical	1.76	-3.69	6.98	7.37	13
Collaboration analogical	0.38	-4.66	6.44	6.97	12
Analogical rule	1.10	-4.16	6.62	7.05	25
Direct rule	-1.64	-6.95	7.33	7.25	23
Identify-the-best	-0.16	-4.88	6.76	6.70	25
Collaboration	-0.26	-6.17	7.47	7.81	23

Note: WS= weak cognitive synergy; SS= strong cognitive synergy; N= number of groups

Our results indicate that there are no significant differences between the collaborative and identify-the-best decision rule $F(1, 48) = 0.09$, $p = 0.75$ for weak cognitive synergy nor for strong cognitive synergy $F(1, 48) = 0.28$, $p = 0.59$. The simple contrast estimate is $t = 3.15$, $p = 0.27$ for weak cognitive synergy and is $t = 0.45$, $p = 0.89$ for strong cognitive synergy. The interaction effect between the two types of manipulations is also not significant, $F(1, 48) = 0.15$, $p = 0.69$ for weak cognitive synergy and $F(1, 48) = 0.005$, $p = 0.94$ for strong cognitive synergy. There are also no differences between the two types of rule inducement, with $F(1, 48) = 2.40$, $p = 0.12$ for weak cognitive synergy and $F(1, 48) = 3.22$, $p = 0.08$ for strong cognitive synergy. The simple contrast estimates between the analogical and direct condition are $t = 3.35$, $p = 0.12$ for weak cognitive synergy and $t = 3.85$, $p = 0.08$ for strong cognitive synergy.

5.6. Discussions Study 1 and isntroduction Study 2

The results of our first study do not provide empirical evidence for our hypotheses. No significant differences have been found between the identify-the-best decision rule and the collaborative rule or between the direct and the analogical type of inducement.

Figure 5.1. *The interaction of decision rule and manipulation inducement on weak cognitive synergy Study 1*

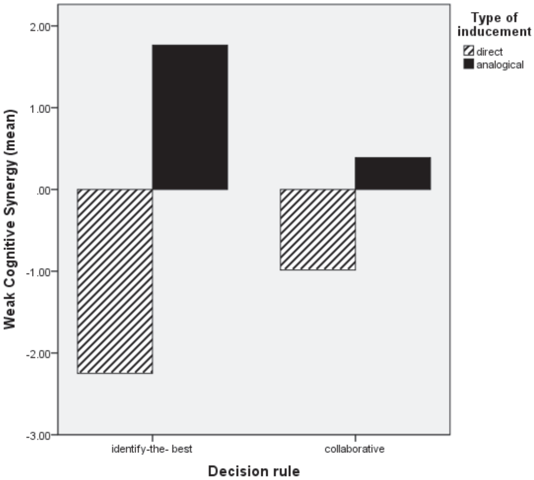
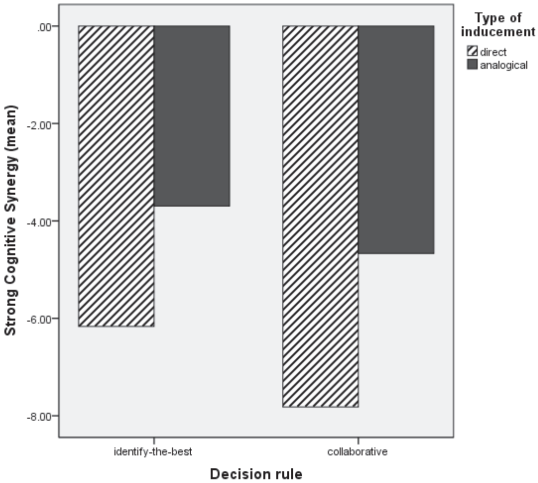


Figure 5.2. *The interaction of decision rule and manipulation inducement on strong cognitive synergy Study 1*



When looking at descriptive statistics as well as Figure 5.1. and 5.2. we further identify that contrary to our expectations, groups perform better in the analogical manipulation than in the direct manipulation, irrespective of the type of rule followed, for both weak and strong cognitive synergy. Interestingly, for weak cognitive synergy groups manage to reach absolute levels of synergy (scores are positive) only in the analogical manipulation, again irrespective of the type of rule followed. This is not the case however for strong cognitive synergy, where synergy in absolute terms is not being reached in any of the four conditions.

Our initial prediction was that groups following directly induced rules will outperform groups following analogical induced rules which involves an extra step in the process of establishing the group decision rules. One alternative explanation for this counterintuitive observation is that participants in the analogical conditions have more autonomy in defining their own decision rule, while groups with the direct rule manipulation have to follow an imposed decision rule. Choi and Levine (2004) indicate that groups that have a choice (high degree of autonomy) in defining their own working strategy are more committed to it and less prone to change it in a subsequent task. Thus, the superiority of the analogical condition observed could be due to the fact that group members have a perception of responsibility for finding a successful decision rule and ultimately are more committed and involved in solving the decision task (Cooper & Fazio, 1984; Choi & Levine, 2004).

In order to clarify whether this alternative explanation is supported by our unexpected observations in Study 1, we have designed a second study in which we contrast four conditions. The first two conditions (self-selection) are the baseline conditions in which groups are allowed to decide their own rule: (1) uninformed self – selection: no decision rule, groups are free to select any decision rule and no further influence is being exerted on the groups (USS) and (2) informed self-selection: groups are free to develop their own decision rule with the ultimate goal of becoming better than their best performing group member (ISS). These first two conditions are considered as baseline for refuting the self-selection explanation because in these conditions groups can decide what strategy to use thus should be more committed to it and more involved in solving their task. The last two conditions are induced decision rules selected from Study 1: CD and IBA.

The goal of the second study is therefore to compare the two induced decision rule situations (CD and IBA) with the two self-selected conditions (ISS and USS). If the group's ability to reach cognitive synergy depends on the degree of autonomy in choosing a decision rule then the self-selection conditions should yield superior synergetic effects as compared to the induced decision rule.

5.7. Methods Study 2

5.7.1. Participants and procedure

Three-hundred-thirty-three students enrolled in an introductory course at a Dutch University (Age $_{mean}$=19.09, 149 females) participated in the study. The students were informed that they will participate in a decision-making exercise as part of their collaborative learning experience and were debriefed at the end of the exercise. We have used a similar task as in Study 1, namely the NASA Moon Survival exercise (Hall & Watson, 1970). The participants were asked to imagine that they are members of a space crew on a ship which has just crashed 200 miles from the meeting point with the mother-ship on the moon. Being left with only 15 intact items from their ship (e.g. matches, food) they had to decide which are the most important for their survival. Therefore, the task of the participants was to rank-order the 15 items from the most to the least important for their survival. In a first step, group members had to rate the objects individually. Next, the students have been assigned to 80 groups (average group size = 4.01) and were asked to perform the same task in groups. Similar to study 1, at the end of the task participants compared their individual performance scores with the group scores and reflected upon the impact of decision rules upon group dynamics.

5.7.2. Manipulations

In this second study, we compared two baseline conditions: uninformed self-selection (USS) and informed self-selection (ISS) with two conditions selected from the previous study: collaborative direct (CD) and identify-the-best analogical (IBA). We have used a between-group design. The 80 groups have been allocated to one of the four conditions: 21 groups to the USS condition, 22 groups to the ISS condition, 18 groups to the CD condition and 19 groups to the IBA condition. Condition CD and IBA have been induced similarly as in Study 1. In the USS condition, groups have been given no indication on how to decide as a group while in condition ISS groups have been instructed to design their own decision rule for 15 minutes while having in mind that the ultimate goal of the group is to become better than the best performing individual in the group. After designing the rule, groups have been asked to employ it as their strategy for the NASA group task. We have used the same measurement for the dependent variable including individual scores, group scores, weak and strong synergy as in Study 1.

5.8. Results

In order to test our hypotheses we have ran a GLM analysis with strong and cognitive synergy as dependent variables. Similar to Study 1, group size, gender variety and the maximum score in the group have been used as control variables. Descriptive statistics and correlations between the variables included in the analysis are presented in Table 5.3.

Table 5.3. *Correlation table with descriptive statistics Study 2 (N=80)*

	Mean	*SD*	1	2	3	4
1.Weak cognitive synergy	9.80	8.76				
2.Strong cognitive synergy	0.01	9.63	0.84***			
3. Gender variety	0.36	0.31	-0.11	-0.08		
4. Individual maxim score	51.01	8.23	-0.04	-0.4***	0.07	
5. Group size	4.01	1.03	0.15	-0.02	-0.12	0.12

Note: ***<.01

Table 5.4. *Descriptive statistics manipulations Study 2*

	Mean		SD		N
	WS	SS	WS	SS	WS/SS
Uninformed self-selection	7.63	-2.47	8.41	9.33	21
Informed self-selection	9.99	-1.36	8.12	8.87	22
Identify-the-best analogical	11.14	3.05	7.97	9.80	19
Collaboration direct	10.71	1.38	10.79	10.34	18

Note: WS= weak cognitive synergy; SS= strong cognitive synergy; N= number of groups

Our results indicate no overall effect of the manipulation upon strong cognitive synergy, $F(1, 79) = 2.31$, $p = 0.08$ or weak cognitive synergy with $F(1, 79) = 1.33$, $p = 0.27$. The maximum score in the group had a significant effect on strong cognitive synergy $F(1, 79) = 14.57$, $p = 0.00$, with a partial $\eta 2 = .16$ and observed power $\pi = .96$ and no effect on weak cognitive synergy, with $F(1, 79) = 0.18$, $p = 0.66$. For weak cognitive synergy, subsequent t-test contrasts indicate no significant mean difference between any of the four conditions. For strong cognitive synergy however, a significant mean difference has been identified between the USS ($M = -2.47$, $SD = 9.33$) and IBA ($M = 3.05$, $SD = 9.80$), $t = 6.51$, $p = 0.02$, CI [0.88; 12.13] as well as a significant difference between the ISS ($M = -1.36$, $SD = 8.87$) and IBA, $t = 7.10$, $p = 0.03$, CI [0.63; 13.56]. The comparison of conditions is also displayed in Figure 5.3. and 5.4.

Figure 5.3. *The impact of manipulations on weak cognitive synergy Study 2*

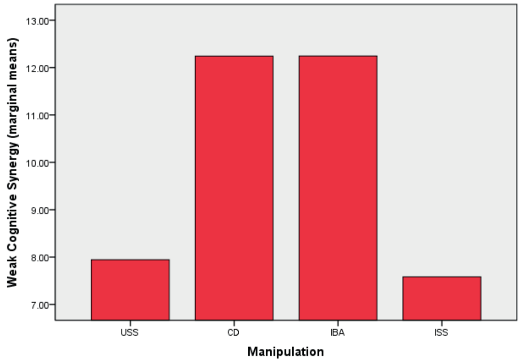
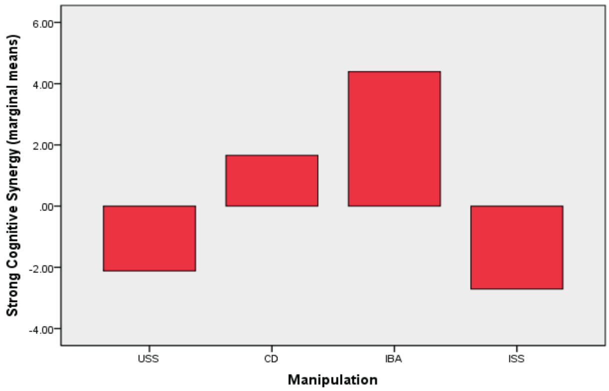


Figure 5.4. *The impact of manipulations on strong cognitive synergy Study 2*



5.9. General Discussion

The results of our first study were not conclusive with respect to the influence of decision rules on group cognitive synergy. One plausible explanation is the small sample size. However, descriptive statistics indicate, contrary to our expectations that the analogical rule appears to be more efficient than the direct one. In order to check what explains the superiority of the analogical inducement we have designed a second study in which we ruled out the degree of group autonomy and involvement in choosing a decision rule as an alternative explanation for our observations. In the analogical manipulation, groups have a large degree of autonomy with respect to the decision rule they have to define and follow when making a decision. Groups are instructed to define their own decision rule by making analogies with successful rules inferred from the scenarios that point towards collaboration or identify-the-best decision rules. In the directly induced decision rules, the degree of autonomy in using a particular decision rule is restricted as groups are being instructed to follow either a collaborative rule or an identify-the-best rule. In previous research the degree of autonomy has been linked with the perception of responsibility for one's decision and commitment to the task, in such a way that higher degree of autonomy leads to higher commitment and responsibility (Cooper & Fazio, 1984; Choi & Levine, 2004). If the higher synergy achieved in the analogically induced conditions were to be explained by the larger degree of autonomy, then in the second study, the two free decision rule conditions (ISS and USS) should have outperformed the CD and IBA. However, the results of the second study rule out this alternative explanation. Groups in the IBA condition (with an analogical decision rule induction) outperformed groups that are given the freedom to choose their own decision rule, with or without the explicit goal of becoming better than their best performing group member (ISS and USS).

The current paper has several contributions, both theoretical and practical. First, we contribute to the decision-making stream of research by indicating the beneficial effects of a heuristic decision rule (imitate-the-successful/ analogical inducement) on decision quality. This type of inducement proves to be a stronger manipulation than the content of the rule in itself and thus practitioners should further consider not only the decision rule used to stimulate groups to perform better than their best performing individual member, but also the way in which this decision rule is being communicated and induced.

Next to the overall beneficial effect of the analogical inducement, the combination of two heuristics (imitate-the-successful and identify-the-best) proved to be the most beneficial for groups in their attempt to achieve strong cognitive synergy. Groups following simple heuristics which are adapted to the contexts in which they are employed, arrive at decisions that outperform the ones reached by groups relying on rather unclear strategies. Identifying the best performing group member and improving his/her performance is a decision rule particularly adapted for strong cognitive synergy, given that the core of strong synergy lies in groups outperforming its best individual member. Our results are also indicative of the less-is more effect (Gigerenzer & Gaissmaier, 2011) in group settings, given that groups following an identify-the-best decision rule perform slightly better than groups following a collaborative rule. This is consistent with simulation studies indicating the superiority of the expert rule (where the expert person in the group is identified and followed) relative to the aggregate rule (information pool from multiple individuals) (Katsikopoulos & King, 2010).

Secondly, we contribute to the cognitive synergy literature. While groups are widely employed in organizations with the assumption that their performance should exceed the performance of their individual members, empirical evidence shows that this is rarely the case (Laughlin, Gonzalez & Sommer, 2003; Gigone & Hastie, 1993; Sniezek, 1990). Our findings indicate that strong group synergy is more likely to be achieved when groups (1) follow analogically induced decision rules rather than directly induced rules (2) follow the identify-the-best decision rule (induced analogically) rather than self-selected rules. This finding does have practical implications for group interventions. Groups which were instructed to self-select their own rule displayed the weakest performance, while the highest synergy was obtained when groups used the CD and the IBA decision rule. Groups in the IBA in the second study were the only ones that managed to reach real levels of strong cognitive synergy. Therefore, our study comes with suggestions on what types of strategies are useful for decision-making groups that struggle to increase their performance and perform better than their best individual member.

5.10. Limitations and directions for further research

Next to its contributions, our study has also certain limitations. First, the sample size used (especially in the first study) is rather small, a limitation inherent in experimental studies with group level manipulations. Our non-significant results between the analogical and the direct condition could be explained by the small sample size. Further studies should try to replicate these results and check the generalizability of our results on different other (larger) samples. Second, the task type used in our experimental studies is a boundary condition for the superiority of the analogical decision rule. We have tested the efficiency of such a rule in a decision-making task where the decision quality reflects how much the decision is aligned with an expert's decision. Drawing from previous experiences of successful groups fits well with the type of task groups have to accomplish. It could be the case that in other types of tasks (e.g. creativity or judgmental tasks) different decision strategies are also effective in achieving cognitive synergy. Therefore, further studies should explore the fit between the type of task and the type of decision rules as an important antecedent of group cognitive synergy. Finally, in the first study we did not control for the effect of time spent on task on strong and weak cognitive synergy. Nevertheless, based on the effects reported in Study 2 we can disentangle the effect of extra time as both IBA and ISS conditions had extra time allocated to prepare the task, yet the difference between the two is significant. This pattern of results is in line with previous studies (Curşeu & Schruijer, 2012b) showing that the effect of the normative framework used by groups qualified the effect of time spent on task on the quality of group decision.

While following Kurt Lewin's logic (Schein, 1996), the way we attempted to change the groups as systems by inducing several decision rules generated interesting insights into the impact of decision rules on strong group synergy. The analogical induction seems to yield the potential for generating strong synergy in decision-making groups. Although analogy-making proves to be a useful tool in a large array of social contexts, the number of studies investigating how analogies work in groups and their functions are rather scant (Paletz, Schunn & Kim, 2012). Further studies should explore the role of analogies and analogical thinking in groups together with the mechanisms that explain the superiority of the analogical decision rules. One interesting avenue of research here could be to connect this type of rule inducement with heuristic decision-making, such as the imitate-the-successful one and shed some light on why this particular type of heuristic proves to be the most adaptive for groups.

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Chapter 6

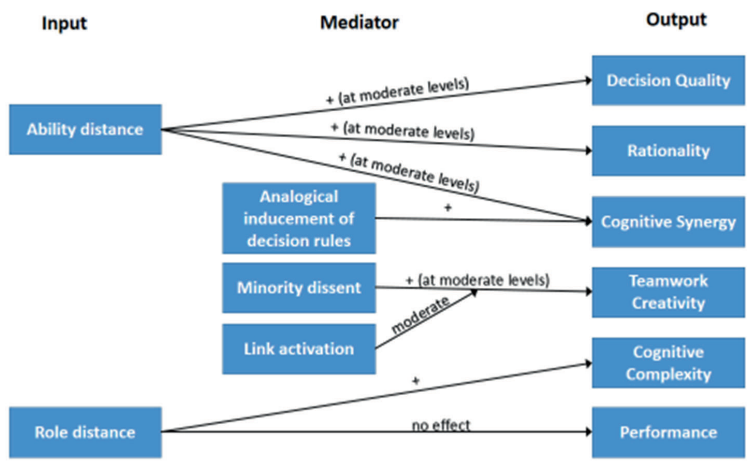
CONCLUSIONS

We have started this dissertation from a broad theoretical perspective in which we position groups as information-processing systems which are constantly involved in processing and transforming information and other resources available into meaningful outputs (Hinsz, Tindale & Vollrath, 1997). We began with a series of research questions which we tried to address along the four empirical chapters. The empirical results presented in this dissertation have brought several contributions (both theoretical and practical) to the small group research stream which I would like to summarize in this final chapter.

6.1. Contributions

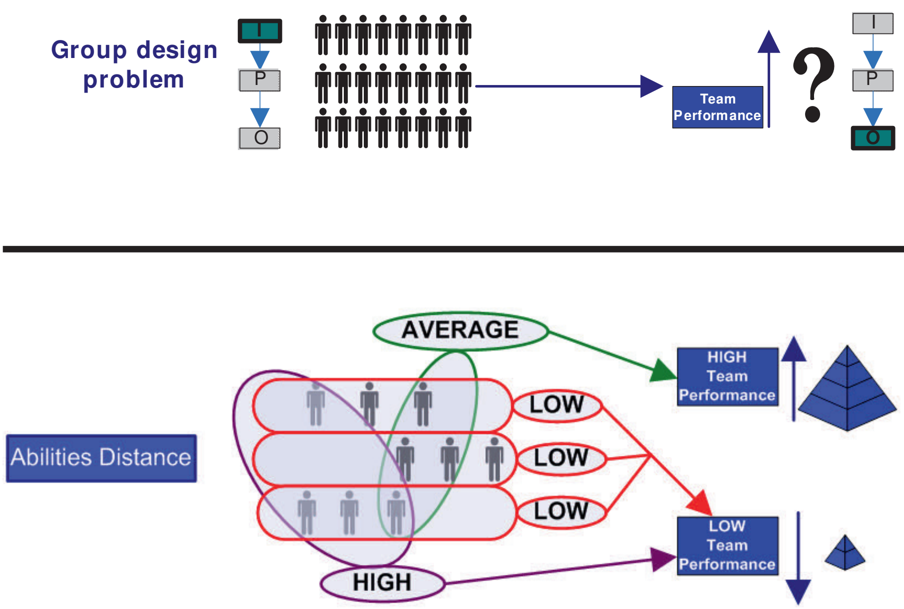
6.1.1. Input-Mediator-Output-Input (IMOI) framework. At a broad level, the current work brings several contributions to the IMOI model (Ilgen et al., 2005). While considering groups as information processing systems we have explored the impact of several input variables (such as distance configurations in abilities and roles) and processes (such as minority dissent, link activation, and analogical decision rule) upon several group outcomes (decision output, rationality, creativity, cognitive synergy, cognitive complexity and performance). We give an overview in Figure 6.1. While developing a conceptualization of cognitive distance and new ways of operationalizing it we contribute to the input part of the model. We developed new mechanisms (link activation, analogical decision rule) and studied them not in isolation but rather as interacting components that influence group outcomes. Finally, one notable strength is the rather wide variability of outcomes investigated, from decision quality to cognitive complexity, group performance and group creativity. Among them, strong cognitive synergy comes to illustrate that of a particular importance is not only if some groups manage to perform better than others but also if groups manage to reach their full potential and succeed in becoming better than the individuals composing them. In the current work we mainly focus on the link between the input and mediator variables on the one hand and the outcomes variables on the other hand. As we are also mentioning in the following subsections, further studies should investigate also the other possible links from the IMOI model, such as the link between inputs and mediators or the transformation of the outputs into inputs again.

Figure 6.1. *Overview of the main findings*



6.1.2. Cognitive distance streams of research. In Chapter 2 we elaborate a conceptualization of cognitive distance in groups and we show that the inverted U-shaped relationship between distance and performance developed in the inter-organizational literature (Nooteboom, 2000) is viable in groups as well. Our study indicates that at moderated levels of cognitive distance groups reach the highest levels of performance, bringing thus an answer to *RQ1 To what extent do distinct cognitive distance configurations differentiate group performance?* The results are replicated in two types of tasks (a decision-making task and a judgmental task) which warrants further support for the stability of our results. These findings have particularly implications for group design, suggesting strategies for composing work groups. Our results indicate that groups composed of members with rather similar but still non-redundant levels of abilities have the highest levels of performance as compared to groups where members' abilities are alike or when there is one group member with a highly detached level of ability (Figure 6.2.).

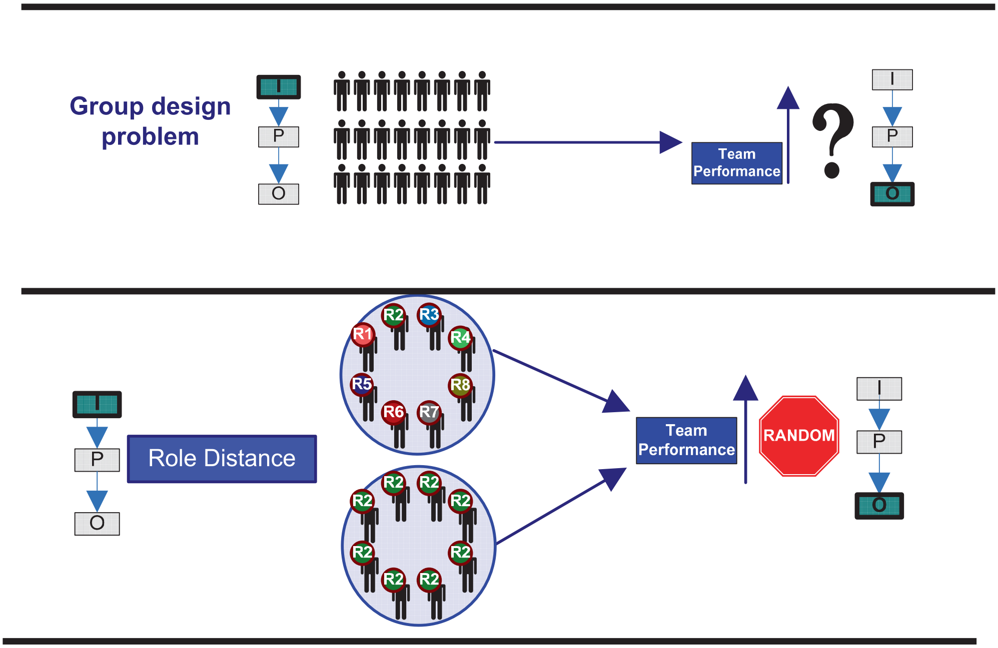
Figure 6.2. *Implications for group design*



Having one expert in the group hypothetically can improve group's performance, given that the rest of the group members can benefit from his knowledge and expertise. However, according to our results, this does not necessarily guarantee an improvement in group performance. During group interactions, the other group members can improve, deteriorate or disregard best member's contributions to the task, as groups have the tendency to discuss mostly shared rather than unshared information (Gigone & Hastie, 1993; 1997) and to marginalize opinions that differ from the ones of the majority (Curşeu, Schruijer & Boroş, 2012). The best performing group member might also experience a motivational loss triggered by the ability discrepancy perceived in the group (Messe et al., 2002) and reduce his/her task involvement. In our studies we do not account for the exact processes underlying the curvilinear effects identified. Thus, future studies should investigate which are the possible processes that generate the highest group performance at moderate levels of cognitive distance: is it individual motivation that drops or are there group processes (e.g. minority dissent, information sharing) that lead to this effects.

6.1.3. Belbin roles theory. Belbin role theory is widely used in practice despite the unsuccessful research attempts to prove that balanced groups (composed of members with distant roles) perform better than unbalanced groups (Partignton & Harris, 1999; Water, Ahaus & Rozier, 2008; Jackson, 2002). While building on the shortcomings of previous studies we test in a comprehensive manner (while using all the available balance indexes) whether group balance is a relevant predictor for a wide range of outcomes in collaborative learning groups: teamwork quality, group cognitive complexity and group performance (both objective and perceived). Our results indicate that with one exception (group cognitive complexity), group balance does not predict any other type of group performance, thus suggesting a negative answer to the third research question: *RQ3 Is group role balance (distance) a relevant dimension for predicting group performance?* As a practical implication, our results suggest that composing groups under the "balance claim" assumption does not necessarily enhance the quality of group processes or performance (Figure 6.3.).

Figure 6.3. *Implications for group design*



One interesting emerging finding is the strong link between the percentage of females and the teamwork quality experienced by the groups. This finding comes in line with recent results reported in Woolley et al. (2010), which indicates that the percentage of women in the group positively and significantly relates to collective intelligence, the link being largely mediated by social sensitivity. An interesting future line of research could focus on exploring the mechanisms through which the percentage of women predicts performance and the consequent implications for group design.

6.1.4. Group creativity. A fourth contribution of our work is to group creativity research stream. In the fourth chapter we develop a conceptualization of group creativity in terms of outcome creativity (which has been mostly studied in the group creativity research) and teamwork creativity (which we propose to be as the novelty and usefulness of interdependent activities employed by the group in order to reach its goal). We further develop a task meant to measure the level of teamwork creativity and investigate how creativity varies as a function of two mechanisms: minority dissent and link activation. By showing that teamwork creativity is influenced by the interaction between minority dissent and link activation we partly provide an answer for our fourth question *RQ4. To what extent does link activation affect knowledge bridging & group creativity?* As groups are socio-cognitive systems, a social process such as minority dissent is likely to interact with a more cognitive process such as link activation in sustaining the creative processes of the group. As implications for practice, our study suggests that the rearrangement of the way in which group members interact with each other in a creative way might be a strategy for enhancing group's creativity. Teamwork is the 'vehicle' through which inputs are being transformed into outputs (Marks, Mathieu & Zaccaro, 2001) and creative reconfigurations of this 'vehicle' can facilitate the quality of team outputs and performance. Our study mainly focuses on the processes that trigger and sustain teamwork creativity. It would be interesting to investigate the impact of teamwork creativity upon other types of group outputs such as performance or output creativity. Another research line could go in the direction of investigating different forms that teamwork creativity can take across tasks and types of groups. For instance, the creative rearrangements of the way in which members interact with each other in a research group could look totally different in other types of groups such as production groups.

***6.1.5. Cross-understanding & representational gaps streams of research*.** Concepts such as cross-understanding (the extent to which group members have an accurate understanding of one another's mental models with respect to what others know, believe or are sensitive to, Huber & Lewis, 2010) and cognitive integration (the ability of team members to understand, anticipate and integrate one another's perspective as a way of reducing representational gaps, Weingart, Todorova & Cronin, 2008) have been advanced for explaining how knowledge bridging and understanding can be achieved in groups. However, these concepts approach the issue of knowledge integration in a rather normative manner by suggesting that groups should integrate and cross-understand each other without actually detailing how this can be done. We contribute to these theories by proposing the mechanism of link activation (derived from cognitive science) as a mechanism through which cross-understanding and cognitive-integration can be achieved. We manipulate link activation in an experimental study (chapter 4) and show that knowledge coming form group members' backgrounds can be successfully used in developing new ways of interacting with each other. The activation we manipulate in chapter 4 is across domains (from taskwork to teamwork). In order to broaden our understanding on how this particular process works in groups, further studies could approach different types of links, such as those directed from task-to-task or teamwork-to-teamwork knowledge.

6.1.6. Group decision-making. Decision-making theory has been recently experiencing a switch in approaching rationality, going from the classical view in which all available information needed to be explored and considered in order to reach the best decision to a rather new approach in which heuristics (as strategies that ignore information) prove to lead to more faster, frugal and accurate decisions (Gigerenzer & Gaissmaier, 2011). We contribute to this new approach by developing and investigating the impact of such a heuristic rule (the identify-the-best rule) upon decision quality. Our results indicate that heuristic rules can be at least as good as the ones in which group members draw on extensive use of information, if not better. This comes with implications for practice, by suggesting that groups do not always need to explore and intensively process all the information available in order to be successful. While following simple heuristics (such as identify-the-best and imitate-the successful via analogy) groups can perform better than when extensively drawing on available information. Further studies should explore how groups can develop their adaptation capacity, given that heuristics are often contingent upon the particular decision situation in which they are employed. For instance, in reaching cognitive synergy (which involves that the group needs to become better than its best individual member) the identify-the-best heuristic seems to be the most ecological. However, in other types of tasks and decisions, different heuristics could lead to better outcomes. Thus, further studied should explore the repertoire of group's cognitive heuristics and its ecological functionality.

6.1.7. *Group cognitive synergy and cognitive competencies streams of research.* Finally, our last contribution envisions the group cognitive synergy stream of research. Studying small groups as entities began (among others) with a few researches showing that groups have the potential of performing better than individuals (Vollrath et al., 1989; Hinsz, 1990). In the same line, groups have started to be widely used in organizations with the assumptions that they must reach levels of performance which are superior to the ones of standalone individuals. However, that assumption does not always fulfils. Reaching synergy, in absolute terms is a rather difficult task and groups sometimes perform worse than their composing members. We contribute to this line of research by exploring conditions under which groups manage to reach cognitive synergy. In chapter 2 we tried to answer our second research question *RQ2 Do groups manage to reach weak and strong cognitive synergy in specific cognitive distance configurations?* while investigating the impact of different cognitive distance configurations upon group cognitive synergy. Although at moderate levels of cognitive distance groups have the highest potential of achieving synergy, synergy in absolute terms is not being achieved (with one single exception, the case of weak synergy in the rationality task). In our fifth chapter we approach again the challenge of finding the key for group cognitive synergy by investigating the impact of specific decision rules. In doing this we try to answer our fifth research question *RQ5 To what extent does the way in which decision rules are induced (analogical vs. direct) influences group's ability to reach absolute levels of* *weak and cognitive synergy?* In our second study we saw an improvement of group's levels of synergy from negative scores (which are indicative for a lack of synergy) to positive scores, which indicate that synergy has been achieved and groups managed to perform better than their individual group members (average or even the best). The topic of cognitive synergy is definitively interesting and challenging. Further studies should explore the impact of other (ecological) decision strategies upon synergy in different types of tasks.

6.2. Concluding thoughts

In the current work we managed to answer a few striving research questions in the small group research area and certainly raised lots more. With an eye to the future, the best is yet to come!

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Appendix A to Chapter 4: Example of Scripts and Link Activation Manipulation

~Doctor Script~

You are a doctor. You are on a holiday sitting at the entrance of your tent, next to Del Passto river. On the other side of the river, beautiful birds are walking along the river bank. You are reading one of your favorite books: "Learning about pain - where are we standing so far?" This is an excerpt of what you are reading:

"In order to experience pain, the first step you need to follow is to take contact with a painful stimulus. This can be done while you are touching a hot device, or when you are exerting a strong pressure of your hand towards a solid surface. The painful signal is then transmitted from the peripheral area (in this case the hand) to the brain via two paths. The first path is via Aδ fibers. This type of fiber conducts the nervous signal extremely fast, 10-20m/s. The second path is via C fibers. The speed of transmission for this second type of pain is of 1m/s. The nervous signal is transmitted to some brain regions that are activated. The brain regions that are activated by the first path are primary and secondary somatosensory cortices. The brain regions that are activated by the second path are anterior cingulated cortex and secondary somatosensory cortices. Once the cortical areas are activated, the subject experiences pain. The first type of pain experienced is brief, pricking and well-localized. The first type of pain signals threat and provides precise sensory information for an immediate withdrawal. Therefore, the first type of pain is an adaptive type of pain which initiates the cease of painful stimuli. This is the reason for which it is much faster than the second type of pain. The second type of pain is less intense but long lasting. The second type of pain attracts longer lasting attention and motivates behavioral responses to limit further injury and optimize recovery. Therefore the second type of pain signals that the part of the body involved is still injured and therefore you need to take care of it – clean it, apply some medicines".

~Psychologist Script~

You are a psychologist. You are on a holiday sitting at the entrance of your tent, next to Del Passto river. On the other side of the river, beautiful birds are walking along the river bank. You are reading one of your favorite books: "Teamwork- the future is in our hands!" This is an excerpt of what you are reading:

"Sometimes people are assigned to conduct projects in teams. Some steps are always taken in order to solve the task. Initially, team members get to know each other, who they are, what is their background and what they know about the task. Afterwards, the task is being divided into subtasks. This division can be made according to preferences (each person takes what s/he likes) or upon expertise (each person takes something in which s/he is good at). The task is divided in such a way that everybody is involved and is doing something of an equal load. If the group is large, the task is divided to pairs of two people. After the task has been divided, each member works on his own for his specific part. From time to time, depending on the task, the group comes together to see what each one of them has been working on. These are a kind of a progress meetings. At this meetings each person tells to the others what he was working on and also listen what the others have been doing. If somebody did not work enough, the group is putting pressure on him. After a series of progress meetings separated by individual working, team members come to arrive to one meeting in which they have to integrate everything they have been working on sofar. First they need to decide who will integrate everything and then all the individual components will be sent/given to that person. When the final project is ready, everybody comes to read it/analyze it and if everybody agrees with the final project, then the project is being submitted".

~Biologist script~

You are a biologist. You are on a holiday sitting at the entrance of your tent, next to Del Passto river. On the other side of the river, beautiful birds are walking along the river bank. You are reading one of your favorite books: "Meerkats: how to survive predators?" This is an excerpt of what you are reading:

"Meerkats are small animals that live in colonies averaging 20-30 members. They usually live in underground networks, with multiple entrances which they leave only during the day. In order to preserve survival, meerkats do follow certain rules. First, there is always one or more meerkats that stand sentry. This sentry happens whenever other meerkats from the group are playing or searching for food at the ground. When predators (martial eagle, the jackal or cobras) are approaching, the sentry gives an initial warning bark. At this time, all the meerkats are hiding in the closest hole they find in their underground network. The first meerkat that enters the hole quickly releases the spot for the second one. He is doing this by going in one of the horizontal corridors connected to the hole. Then, the second meerkat has enough space to enter the hole. In a similar vein, (s)he makes room for the third meerkat and so forth. The meerkats manage to synchronize in such a manner that no meerkat has to wait for another while entering in the underground. In this manner, they significantly increase their chances to survive the predators.
In the underground, they are deciding about their strategy. Usually the group leader decides which strategy to adopt. From time to time the sentry goes out to see if the predator is away. If the predator is not away then it continues to signal the other

group members via specific sounds. One way in which the meerkats choose to defend themselves is via mobbing behavior. All the meerkats come together and attack the predator until he dies. Depending on how they manage with these threats survival of the meerkats gang is maintained or not".

~Link activation examples~

1. *Working on your own for a subtask is like pain transmission!!*

2. *Working on your own for a subtask is like the hiding behaviour of meerkats when predators approach!!!*

Appendix B Chapter 4: Coding scheme for teamwork creativity

~Novelty~

How much the solution differs from a typical student script? It is considered to be novel if it includes:

1. Components of tight motion synchronization (e.g. when one member starts jumping on log 1, the other one starts jumping on log 2; 1p- triple synchronization; 0.5p - double synchronization;

2. 2. the creative manipulation of external environment in conjunction with teamwork; (e.g. participants shout at the birds to scary them and then have time to go 2 by 2 to reach them; or they turn around a log to cross on it); The inclusion in the solution of materials which were not at group's disposal are not rated as creative (e.g. the use of fiber). The groups were warned they do not have any additional material at their disposal which they can use to cross the river. 1p –the presence of any creative environmental manipulation in conjunction with teamwork;

~ Usefulness~

Is teamwork helpful for goal achievement? The ultimate goal of the task is to save the six birds. How many birds are saved at the end? The task is made in such a manner that participants either manage to save 0, 4 or all 6 birds. On the other side of the river the number of people that can arrive is either 0, 2 or 3, which means 0, 4 or 6 birds saved. All other values are not possible. Points given: 0p - no bird saved; 1p - 4 birds saved; 2p - 6 birds saved;

~Quality/Teamwork richness~

How much teams used teamwork as a mean to solve the task as opposed to (just) manipulating the environment?

1p - all members were involved in the task;
1p - all members survived;

Appendix C Chapter 4: Experimental task: save the birds

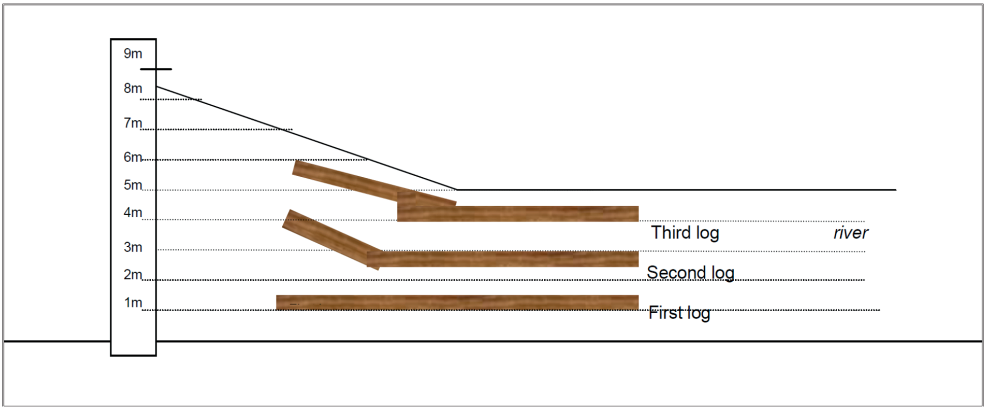
Save the birds

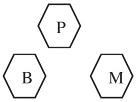
Now, think of a way to cross the river and save the 6 rare birds from being intoxicated while considering the following constraints:

1. All the three of you need to reach the other side of the river to take the birds; there are 6 birds in total, and each of you can only hold 2 birds;
2. The birds are getting into water in a ritualised manner, every day at 12 o' clock. Given that its 11h 59 min and 58 s you need to find a way to cross the river in 2000ms (this would be precisely 2 s) or less.
3. The first log (piece of wood that floats on the water) cannot sustain more than 2 people. If three people step in, it will sink and all the people on it will get drawn & intoxicated.
4. One person can never be let alone on any of the three logs. It will lose its balance and sink.
5. You cannot skip logs because each one of you can jump a maximum of 2.2 m. The distance is too high to jump from the river bank directly to the second log.
6. From a stationary position, a person can jump a max of 2.2 m at a speed of 3.2 m/s. Given your science-related job, you are not in such a good physical condition. Therefore, you are only able to jump from a stationary position.
7. You are not allowed to position yourself in-between logs!

You have 20 minutes to find a solution and describe it on the Solution sheet!

Here you have a drawing of the river:



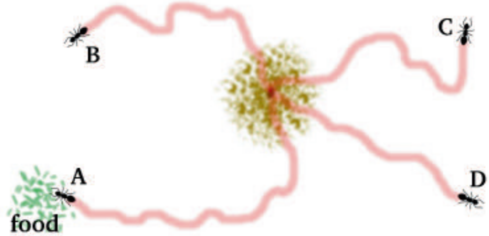


Appendix D Chapter 5: Analogical manipulation

Individuals in groups: how can ants identify the successful member in their colony?

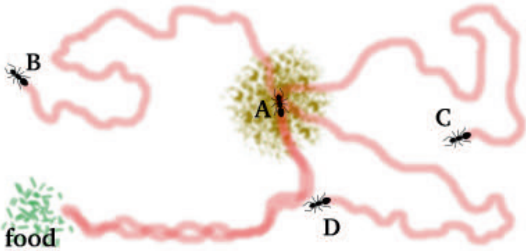
Ants are social insects which means that they live in large colonies or groups. One of the most challenging jobs that they have is to gather food for their colony. **How do ants manage to find food? The collective well-being depends on this.**

At the beginning, the colony starts out with no information about the location of food in the environment. Therefore, each individual ant starts searching for food by walking randomly. In order not to get lost from the nest, each ant leaves a trail of pheromone as it looks for food. In the picture below you have 4 ants. Ant A managed to find food, the others do not.

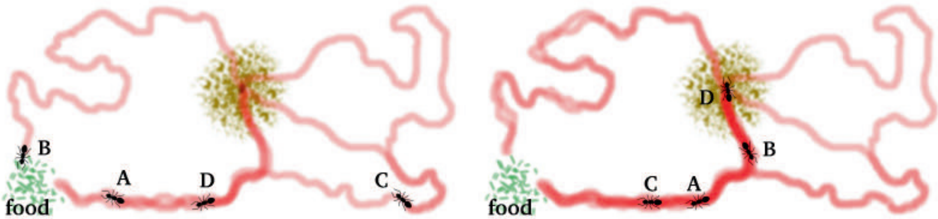


If each of the ants continues to search individually, they will loose time and energy with no desired outcome for their colony. What do the other ants need to do? **They need to identify which is the successful ant and follow it.** Successful in this context means that the ant has found food. Now, how can ant B, C and D (which were unsuccessful in finding food) identify that A actually has found some food supplies?

Smartly, on its way back to the nest with food, A signals the successful path while laying down even more pheromone on that path. When ant D for instance randomly approaches the strengthened path, she will soon realize that path leads to food. Therefore, it will follow it.



Once ant D discovers the correct path, it will try to improve it. Therefore it lays down another layer of pheromones on the successful path. In this way the other ants know even stronger which is the correct path. And so will do the other ants until everybody knows where the food is.



To conclude, ants manage to reach their task (of finding food) by identifying which ant is actually successful in finding food , follow her and improving even more the way to the food.

Appendix E Chapter 5: Group Strategy

GROUP STRATEGY

A group task is coming in which you will have to rank the same 15 items in the correct order. You will be successful in the task if you manage to get the closest ranking to the expert ranking. Before proceeding with the task, discuss/plan/design/find out the best strategy for your team to be successful.
Attention, the strategy should be related with teamwork, or how you should work as a group.
!!! HINT: You might get interesting cues from the text with the ants…

Write three ideas/major points of your successful strategy here:

1.

2.

3.