Self-organising processes of task allocation

Zoethout, K.

Chapter 7
Conclusion

In this section I will relate the conclusions of the experiments in the different chapters, to the conditions of self-organisation that Morgan (1986) has described. The conclusions of chapter two focus on the paradox that a model can be both simple and integrative. The conclusions of chapter three involve the verification of the model and the program. The conclusions of chapter four are related to the condition of 'minimal critical specification'. Chapter five and six focussed on the variety of demand (five) and supply (six) in relation to the behaviour of specialists and generalists. Their conclusions are related to the conditions of 'requisite variety' and 'redundancy of functions'. The condition of 'requisite variety' is somewhat interwoven with the other conditions, for instance because less redundancy and less critical specifications implies less variety (see also Molleman, 1996). In all experiments, expertise and motivation are process variables. They are related to the general concept of learning. I end with a final conclusion concerning this thesis.

7.1 Modelling Self-Organising Processes of Task Allocation

A multi-agent model that describes self-organising processes of task allocation in a comprehensive way should preferably encompass different psychological theories and models at both the individual and the group level and should also interrelate these levels. This, however, may also easily lead to complications. The first complication is related to the multi-disciplinary nature of such multi-level research. A combination of different models at different aggregation levels may result in misunderstanding between the different disciplines these models come from (see also Klein & Kozlowski, 2000). As a result of this, we may end up with an unclear model that does not contribute to scientific progress in the respective disciplines. For instance, for a sociologist the term structural learning refers to changes of the structure of the social network. However, for a cognitive psychologist, since learning can be described by means of change of neural connections, the term may as well refer to changes of the structure of the neural network. The second complication is related to 'Bonini's paradox': 'the more realistic and detailed one's model, the more the model resembles the modelled organisation, including resemblance in the directions of incomprehensibility and indescribability' (Starbuck, 1976, p 1101, cited in Weick, 1979). This paradox yields for simulation models in general (Weick, 1979), but certainly applies to multi-disciplinary models.

This implies that my model needed to be both integrative and simple. This evokes two questions. First, have I been able to build a model that was multi-disciplinary and yet easy to comprehend? Second, if yes, how did I manage to do so? To answer these questions, I am going to explicate how I built the model. First of all, all kinds of approaches, disciplines and views that are related to a certain phenomenon have one thing in common: the phenomenon itself. Therefore, when I build the model I tried not to focus on the theories and models underlying it itself, but considered them only as a vehicle that could lead me to the collection of phenomena that they describe. The next step was to describe this collection of phenomena in simple terms. In my case, this implied the use of some neural network concepts such as activation, excitation, inhibition, threshold, and connection. The result of this model-building-strategy was a model that was funded on empirically based theory with an important benefit: the model was based on a collection of underlying phenomena and was not restricted to a specific research area or discipline. Therefore, it was not only capable of integrating the phenomena that the underlying theories described, but it turned out that it could describe other relevant phenomena as well.

To explain all this I will give three examples. The first example considers the integration of multiple theories into a simple description: Both the similarity/attraction effect (Newcomb, 1960), the proximity/attraction effect (Festinger, Schachter & Back, 1950), and the effect of mere exposure (Zajonc, 1968) describe the general principle that is also formulated as Hebb's learning rule (Hebb, 1949). This rule describes that the simultaneous activation of two neurons increases the change for a connection to grow between them. If we would replace the term 'neurons' with 'elements' we could use Hebb's learning rule as a general principle that describes the phenomenon of connection changes at both the neural and the social aggregation level (Zoethout, 1994). Besides, it is much easier to model this general principle than to incorporate different social psychological effects into a model.

The second example illustrates how my model not only describes phenomena related to the underlying theory, but proposes a description of another relevant phenomenon as well. My model describes the influence of motivation on performance, by considering motivation as a skill component. In this way the motivation of an agent is a function of the motivation of his active skills. During the allocation process the agents start with what is called an 'initial choice' This resembles the part of the task that they individually want to perform, based on their expertise and motivation. As a result of this 'initial choice' the agent start to negotiate which leads to, what is called the 'final allocation'. According to the model, a discrepancy between 'initial choice' (what they want) and 'final allocation' (what they get) may result in motivation loss because then the agents are forced to use skills for which their motivation is lower. This phenomenon is described in theories on extrinsic an intrinsic motivation because studies indicate that in general, intrinsic motivation leads to higher performance than extrinsic motivation (e.g. Hirst, 1988). Although I did not model nor study the differences between extrinsic and intrinsic motivation, the phenomenon itself is relevant for describing the relation between motivation and performance. Moreover, my model describes this phenomenon although it was not based on it in the first place.

The last example shows how a complex property can be modelled in a simple way. This concerns the negotiation process between the agents itself. Both the individual decisions and the negotiation process describe whether or not particular skills should be used. In the model the mutual influence of agents is described as mutual influence of skills (see Figure 4b in chapter two). At the skill level, influence is based on expertise, motivation, thresholds, and a set of inhibitory and excitatory connections. This influence results in a state in which a skill is used or not. An agent is being defined by means of a set of skills. At the agent level, it seems that each agent has a specific preference, makes an individual choice on the basis of that, influences the other agents to let him proceed in what he wants, and may become de-motivated when he cannot get what he wants. However, a negotiation process concerning all these elements is only possible for a being with cognitive and social abilities that enable him to choose for himself and oppose others that interfere with this choice. Furthermore, he would need an internal representation of his co-workers and the task. And yet, with a model as simple as mine, without all these properties, it is possible to describe these complicated processes.

These examples illustrate that my model is both simple and integrative. The design of a simple model forced me to describe the common phenomena as studied within the different disciplines. Therefore it does not create confusion of tongues but offers a platform for integration instead. Further, a focus on simplicity protects us against the disadvantages of Bonini's paradox. Finally, the model satisfies two benefits of simulation models in general as mentioned in the introduction of this thesis (see also Arrow et al. 2000): first, it does not tolerate vague ambiguous theories because it forced me to explicitly formalise theory into computational algorithms. Second, it offers a possibility to integrate all kinds of theories and models related to the same phenomenon.

7.2 Verification of the Model and the Program

After formalising the model into the simulation program called WORKMATE, I conducted three experiments to verify the model and the program (Chapter 3). The first experiment in which I studied the relationship between specialisation and coordination time showed that WORKMATE generated dynamics in accordance with the expectations as derived from the model. The data indicated that in a stable condition without boredom, the system would always end up in a stable state. This state was reached according to the principle that the best becomes better and the worst becomes worse. This principle holds that the use of a particular skill leads to the improvement of that skill. This increases the chance that this skill will be chosen again in the future, which leads to further specialisation in that skill, while the other skills are forgotten, etc.

The second experiment that concerned the relationship between task variety and coordination time again showed that WORKMATE worked according to my model. The results indicated a similar specialisation effect as described in the first experiment within one task. From one task to another the coordination time increased, which indicated that it took more time to allocate the new parts.

The third experiment that dealt with the consequences of boredom effects indicated that WORKMATE was able to generate emergent phenomena. Skill use implied that agents learned and enhanced their expertise, while at the same time got bored and less motivated to do that task. Not using a skill implied that the agents lost expertise, but also recovered from boredom for this task. This causes task rotation to occur, which showed that the model was able to produce self-organising processes that lead to new properties at the group level.

7.3 Task Rotation and Minimal Critical Specification

In chapter four I varied different types of self-organisation: self-organisation (purely bottom up processes), semi-self organisation (bottom up processes with little top down restrictions), and no self-organisation (only top down restrictions). These experiments are related to the condition of minimal critical specification that states that only critical issues should be fixed (Herbst, 1974). The results showed that in situations where task rotation could emerge because of self-organisation, the system performed better than in case of no self-organisation. These results are in accordance with the condition of minimal critical specification. .

Further, I varied different levels of boredom and introduced the independent variable of task rotation frequency, which, of course, did not apply to a condition in which the agents were free to self-organise, where task rotation was more an outcome or process variable. As regards boredom and recovery, I found that a decrease in the boredom and recovery rate resulted in agents delaying their start of task rotation. As soon as the boredom/recovery rate dropped beneath a certain point, for two reasons the agents did not rotate anymore. First, at the time the agents got bored enough to rotate, their expertise level had become lower than the threshold, which made rotation impossible. Second, the long period before the first rotation caused the agents to specialise in a single skill, which weighted stronger than the motivation loss. This implies that a task that leads to high levels of boredom will be performed better than a task causing a low level of boredom, because in case of highly boring tasks rotation will emerge and in case boredom comes slowly task rotation will not come. As regards to the task rotation frequency, I conclude that with respect to expertise, the decrease in the rotation frequency has the same effect as the decrease in boredom/recovery: as I stated, a decrease of boredom/recovery delayed the start of task rotation. By definition, a decrease in rotation frequency leads to the same.

7.4 Task Dynamics and Requisite Variety

In chapter five I tested hypotheses that were based on the condition of requisite variety. This condition implies that a stable environment matches the best with a mechanistic centralised organisation, a turbulent environment demands an organic organisation with high individual autonomy, and somewhere in between, autonomous teams would match the demands of the environment the best (Burns & Stalker, 1961; Molleman, 1998). To test this condition I used a design with groups of specialists and generalists under different conditions of task variety. But although it turned out that in stable situations the specialists performed better, the generalists did not outperform the specialists in turbulent situations. Instead, since there is hardly any space for learning in turbulent situations, the behaviour of specialists and generalists becomes more similar and, consequently also their performance. Although these conclusions more or less comport with existing research, the experiments did not clearly indicate the relation between organisations and environment that can be expected on the basis of the condition of requisite variety.

An explanation for this can be found in the way in which we defined specialists and generalists. Specialists are being defined as minimal generalists, with the capacity to perform all parts of the task but with a specific preference for a small portion. Generalists are being defined as agents with no preference for a specific part of the task. New tasks however imply the use of new skills. Neither the specialists, nor the generalists were equipped with high expertise regarding these skills. With regards to the specialists, this is a logical consequence of being a specialist. But the benefit of generalists of being able to use all kinds of different skills does not apply here. Moreover, empirical studies indicate that 'minimal generalisation' is sufficient to deal with variety (Van den Beukel, 2003). Thus, in my research the definition of generalists does not hold because they lack the ability to deal with new tasks and the definition of specialists does not hold because they are defined as minimal generalists, being able to deal with variety. Therefore, although the study revealed some principles related to Ashby's law, this condition still needs more research.

7.5 Task Rotation, Flexibility and Redundancy of Functions

In chapter four I introduced the concept of task rotation based on the notion that agents start to re-allocate tasks when their motivation to proceed with the same action was too low. Of course the process of task rotation only occurs if the team members share some skills. This refers to the condition of redundancy of functions, which constitutes a prerequisite for task rotation to emerge. Task rotation is the most important self-organising principle in the studies I described in this thesis, not only because it enables a group to cope with boredom, but it offers a way to flexibly adapt to new situations as well.

The chapters five and six describe experiments about the flexibility of self-organising task groups. Chapter five describes how a task group reacts upon external changes such as task dynamics. Even the least flexible group that I tested, the specialists, still consists of minimal generalists, because a group with real specialists, i.e. without any redundancy of functions, would not be able to cope with any changes at all, which would only lead to trivial results.

Chapter six describes processes related to internal changes such as turnover. I simulated the task allocation processes of two artificial work groups that both required an extra worker. The group in the no fit condition represented a project team in which the whole project was assigned to the complete group, whereas each member contributed evenly to the whole task. The group in the fit condition represented a project team that recently lost one of its members. To both groups, one newcomer was added. This could be a specialist or a generalist. The results showed that the generalists performed better than the specialists in the no fit condition and the specialists performed better than the generalists in the fit condition. However, an effect that was much stronger indicated that the characteristics of the newcomer did not matter that much: In the fit condition every newcomer improved the group performance, whereas none of the newcomers contributed positively to the group performance in the no fit condition. In groups without the possibility for the newcomer to fit in, the newcomer was just in the way, which led to performance loss. Since in all conditions the adaptation processes are processes of task re-allocation, these processes could only occur because of redundancy.

Further, without redundancy, the group in the fit condition would not have been able to perform its task anymore until the newcomer arrived because none of the workers would have the skills to take care of the work of their former co-worker. The group in the no fit condition and the newcomer would not have been able to mutually adapt at all, because in this group adaptation automatically implies re-allocation, and re-allocation is impossible without redundancy.

Therefore, I conclude that none of the experiments on self-organising processes of task allocation as described in the chapters four, five and six, could have been conducted without a certain minimal level of redundancy of functions. It is conditional for task rotation and for self-organisation.

7.6 Expertise and Motivation Processes and Learning

As I stated in the introduction, the condition of double loop learning, i.e. monitoring the tasks (including its goal) itself and constantly looking for better alternatives, did not apply to the experiments in this thesis. Instead, the agents had to perform a rather abstract task that was designed by me. This implies that although I studied processes of self-organisation, I explicitly formulated the context under which this took place. As the condition indicates, in real life a self-organising system defines its own context (Varela, 1984). This touches the fact that the question whether a system is self-organising or not, is defined by the boundaries the researcher defines. This leads to discussions and reflections I choose not to address in this thesis. Instead I focused on the internal learning principles and mechanisms in relation to Krippendorf's (1986) definition of learning that I described in the second chapter of this thesis. This definition states that learning can be considered as a process of increasing success in a fixed environment (Krippendorf, 1986). This definition not only applies to increase in expertise, but also refers to the increase in motivation, since motivation and performance are positively correlated (Hackman and Oldham, 1980). Furthermore, it refers both to individual and to structural learning. But, as I stated in the introduction, the notion of structural learning is only used in the general model that I described in chapter two, but has not been part of the experiments I conducted. Therefore, I only now describe principles related to individual learning. Four principles are considered as the most important with respect to the description of the processes that I studied.

The first principle involves the specialisation of the agents. According to the model, the results of the experiments in chapter three demonstrate that without the influence of boredom, agents simply specialise in the skill they use when they start performing a task. I called this principle: ‘the best become better and the worst become worse’. Evidently this results in an increase of performance. The second principle involves the boredom of the agents. According to both the model and the results of the experiments in chapter three, four, and five, the boredom concerning the skills that the agents use for a longer period of time increases. Evidently this results in a decrease of performance. Experiments showed that both principles together lead to a performance decrease. This shows that boredom had more effect than specialisation, which can be explained with the parameter settings of boredom and learning and the consequences of the boredom and learning functions that the formulas describe. But the combination of both principles had another effect: under the circumstances as mentioned in the description of the experiments, the agents started to re-allocate their task. This third principle is called ‘task rotation’. These three principles form the basis of the complex mutual interaction between expertise and motivation, task performance, and task allocation, that the model describes. The last principle is a consequence of the external and internal dynamics I described in the chapters five and six. It holds that the agents start using their best skills, then their second best skill, and finally finish using their worst skills. For two reasons, this principle causes performance loss when a task is nearly finished. First of all, by definition the worst skill itself indicates the lowest performance. Second, keeping one single skill to the end unused, results in the absence of possibilities for task rotation as a way to cope with boredom. This results in high motivation loss and as a consequence to this, low performance.

Although these principles are logical consequences of the model, the complex mutual interaction between the variables does not result in trivial results. Instead, as the principles showed, the model offered a way of systematically describing the individual learning processes and the relationship of their underlying mutual relationships.

7.7 Final Conclusion

In my experiments I related three conditions of Morgan’s ‘principles of holographic design’ to self-organising processes on the basis of behavioural theory. In relation to these experiments, the conditions of minimum critical specification and redundancy of functions appeared to be more or less evident: more specifications imply less individual freedom, because behaviour is forced upon the workers, which implies less possibilities to self-organise. Without redundancy of functions, workers are not able to choose what to do, not because they are not allowed to do so, but because they simply do not have the potential to choose another task.

It is less evidently to relate the condition of requisite variety to self-organising processes. According to this condition, a task with little or no variety matched the best with a group with more specifications and less redundancy, i.e. low variety (Burns & Stalker, 1961; see also Molleman, 1996; 1998). However, the only relation with self-organisation I would be able to give is that a group with specialists, representing a group with low variety, shows the best performance concerning a task with low variety. Furthermore, high task variety results in a slight tendency towards generalisation, i.e.

high redundancy of the workers. However, although the law of requisite variety indicates that in the latter condition, generalists would outperform specialists, this did not happen. Moreover, the tendency of the group of specialist to behave like generalists is the result of the inability to specialise because of the high task variety, which is more or less trivial. Finally, high task variety would not only imply high generalisation concerning the original task to perform, but would also indicate expertise concerning the new tasks to come. Therefore, on the basis of the results of the experiments I must conclude that the process of generalisation and specialisation within a group, caused by different levels of task variety, is not fully understood and needs further research. Nevertheless, I will conclude this chapter by stating that although this thesis only partly succeeded in relating self-organising processes to the conditions that Morgan has stated, it was successful in relating self-organising processes to behavioural theory