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The Emergence of the Glass Ceiling: A Study on the Role of Nature and Nurture by the Use of an Agent-Based Model

by

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Abstract

The glass ceiling problem refers to the difference in career opportunities between men and women. It can be seen as an emergent property of society, where interaction on the individual level results in a seperation of the population on the collective level. Because studying the origins behind this phenomenon is difficult, a multi-agent based model is proposed where being social is captured in the core of the agents. The model is used to simulate a playground for chilldren, by letting the agents play different types of games. Their behaviour is driven by needs such that they show believable decision-making. The objective is to study wether biological differences between boys and girls, i.e. nature, or social interaction, i.e nurture, leads to two separate groups of boys and girls. It will be shown, however, that is rather the combination of the two factors, the so-called self-organization, that results in the emergence of different groups, similar as in the glass ceiling problem.

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Chapter 1

Introduction

There are many studies pointing to differences in career opportunities between men and women in Western countries, the so-called *glass ceiling problem*, even after years of emancipation. Salaries, promotions, manager positions: It still looks like men are favoured over woman, even though in some cases women have at least the same skills or expertise. Although the glass ceiling captures the differences in treatment at the workplace in particular, it actually goes beyond that.

Boys playing football and girls chatting, it seems like a common scenario that can be found in many playgrounds. However, girls playing football and boys chatting is somehow a rare situation. In this example of the boys or girls playing football, where clearly no work-related environment exists, one can notice that already with children the expectations between boys and girls are different. It looks like the difference between men and women in the workplace can be traced back to an earlier stage, namely already with children just playing. How is it possible that seemingly there is a different 'men' class and a 'women' class?

Besides the fact that there is ofcourse a biological difference between boys and girls, also called the influence of *nature*, social influences make that children actually get aware of this gender concept. It would be hard to find out from whom children learn this. Not only parents, but also friends, teachers, and all other kinds of social institutions can have an influence on that. These days also (social) media and games can emphasize the differences between boys and girls. All these examples of where the awareness of differences can come from, is called *nurture*. Roughly speaking, nurture can be seen as all the influences emphasizing different behaviour, besides natural differences already existing by birth.

Social Groups

One of the phenomena that captures the influence of social interaction is the existence of *social groups*. According to [1], a social group is a group of people, which act according norms and values which are typical for that group. Norms are (often informal) rules of behaviour. Complying to or violating the norms can have consequences. Examples of groups are one's family, a group of colleagues, friends

from high school, etc. An institution is a group whose rules are formalized (often by law) and become independent of the actual people in the group. Examples are schools, universities, companies or even a country. A social group only exists in coexistence with other groups.

Accordingly, each member of a group has a *social identity* [1, 2, 3] that corresponds to the values of the group. Because people are members of multiple groups, they have, beside their *personal identity*, multiple social identities. When being in a group, people behave according to the corresponding social identities.

A lot of social groups, with the corresponding behavioural rules and values, exist for a long time. These groups manage to maintain themselves because new members are easily being treated in such a way that they become a member too. For instance, new children on a primary school are invited to play with dolls if they are a girl, or play football when they are a boy. Furthermore social effects emerge from the coexistence of multiple groups. One of these social interactions is the in/out group effect, where people of the same group (in group) favor each other and dislike people belonging to other groups (out group).

How these groups are established is not trivial to answer. It is the consequence of multiple individuals acting and interacting on individual level. However, the social groups themselves need to be observed from the collective level.

This difference between this behaviour on the individual, or *micro*, level and collective, or *macro* level was first mentioned in the field of social-economic literature [4]. The use of relatively simple rules of action on the micro level causes emergent behaviour on the collective level that can be interpreted as being complex or even intelligent. Nowadays a lot of examples about systems with multiple entities working together can be found in biological systems, for example [5, 6, 7, 8]. By dividing behaviour into the micro and macro level, one can gain insight on the seemingly intelligent behaviour of the whole, by studying the characteristics of the rules on individual level.

The glass ceiling as an emergent collective behaviour

The glass ceiling problem can be seen as the collective behaviour that is caused by individuals acting in a certain way and interacting with each other. The question now is what type of behaviour and what type of interaction results in this.

Nature The question is then wether a different treatment of men and women exists because, for instance, are men better in managing than women? Are boys better at playing football and do most of the girls therefore not like to play football? If these questions can be answered with a ‘yes’, it implies that the emergence of the glass ceiling can be assigned to a natural cause: Men and women simply differ biologically, and therefore they are found in situations where they fit the best. This would be an argument for the nature side of the problem.

It is already clear that the glass ceiling can not just be explained by nature. For example, identical twins raised in different environments will not behave in the exact same way, with the same type of clothes and the same job etc. In other words, if the difference in treatment between men and women in a working environment could be explained by only natural factors, the social environment would not have an influence on that. This would also argue for a clear difference in cognitive behaviour of babies, nevertheless only small differences can be found between newborns boys and girls [9]. That only those small differences cause a large effect in the future is not very likely.

Nurture If it is not likely that the emergence of the glass ceiling can be explained by just nature, it argues for the role of nurture, i.e. influences from the social environment. Like in the example of boys or girls playing football, a difference in expectations of men and women can already be found by young children. This suggests that social influences should start from an early age too. Considering the fact that for newborn boys a blue room is preferred and for a newborn girl a pink room, the gender difference is actually emphasized since birth. Furthermore, if there already exists a stereotype for men and women, newborns will be pushed in that same direction by society. In other words, from a young age children learn that there is a difference between boys and girls, and that they should behave like that too.

Self-Organization A final cause for the emergence of different social groups might be a combination of the previous two, i.e. nature and nurture, the so-called *self-organization*. By social interaction the biological differences between boys and girls, although these differences are small, are emphasized. In other words, the interaction between those differences and the social environment makes that eventually two separate groups emerge, both with their own behavioural rules, values and identity. Although nurture looks like a plausible cause, would that difference in social treatment of men and women also exist if there were no natural differences and just nurture influences? If not, this argues for the role of self-organization.

With these three main directions of where the glass ceiling emerges from pointed out, the main question of this thesis becomes:

Can the social emergence of the glass ceiling be explained by just nature factors, nurture influences on individual level, or by self-organization?

The influence of nurture, and therefore also the self-organization, however, is hard to study empirically. First of all, it is ethically impossible to create an experiment with people that act in a experimental society in order to manipulate the variables. Secondly, the process of the emergence of different social groups takes very long and, again, is hard to reproduce. What is left is observing the existing glass ceiling and trying to trace back possible causes, but it is nearly impossible to distinguish between the influences of nature and nurture. For example, seeing girl playing with dolls more often than boys can be because different reasons. Is it in the nature of girls to take care of something, which argues for a natural cause, or is it the assumption that girls are supposed to play with dolls and therefore get one at their second birthday? For this reason, another research method should be found in order to study the cause of the glass ceiling problem.

Computational Research Methods

A straightforward solution of getting insight in this problem is by using a computational model. As mentioned by [10, 11], for already a long time computational modeling has been an important tool for simulation. It has advantages compared to other type of models [12]. These computational models can be used testing theories about human cognition [10]. One should have a skeptical attitude towards proving these theories, yet insight in and little evidence for the theory can be obtained. This means that the use of a computational model gives the opportunity to study social behaviour in a relative easy way, as long as one keeps in mind that it is not a way of proving social theories.

A more frequently used modeling tool is a *multi-agent based simulation* (MABS). Instead of using mathematical formulas and equations that describe the dynamics of the model, multiple entities are used that communicate with each other. These interactions might give rise to collective behaviour. Therefore a MABS is useful for simulating collective behaviour.

In [4] an example is given of one of the first MABS's, representing a complex system and how it can be used as a tool to get more insight on both the micro and macro level. The model showed a simplification of two groups of different people living in the same community. In the model two groups of agents had different tolerance rates about how many agents of the other group they want to be surrounded with. The rule for action on micro level was that if this threshold was passed, find another place to live. The computational model showed how with this micro rule spatial separations of the two groups occured, being the macro behavior. This shows how instead of keeping track of moving behaviour of societies for over years, a simplification can be studied in much less time. Also insight on the influence of different rules on micro level can be obtained by easily manipulating them.

Scope of thesis

The scope of this thesis is to study how social interaction can affect a separation of a population and the emergence of new social groups. The motivation for this research is the problem of the glass ceiling, and concepts included in the model will be related to this. However, other social related problems or questions can be studied by using the model, but will not be captured in this thesis. The focus in the study will be on both nature and nurture factors, in particular the self-organization that rises from the interplay between the two. This will be done be building a multi-agent based model. Two important requirements should be satisfied by the model. First of all, in order to create believable behaviour, the agents in the model should have believable human-like behaviour too. Only in that way conclusions drawn from the model can be expand to the emergence of the glass ceiling itself. Secondly, the model should contain a framework wherein social interaction is integrated.

The playground: A computational model to study the emergence of the glass ceiling problem

In order to study the possible origins behind the emergence of the glass ceiling, a computational playground is simulated. The idea behind this specific example comes from [13] and the motivation for the playground is twofold. First of all, a playground is meant for children, who are not as influenced by society, institutions and other environmental factors like adults are. Adults are more shaped by their social environment and the consequences of biological differences is harder to find. Therefore, the focus of the simulation is on the children and the interaction between them. Secondly, the playground represents an environment where different types of activities are chosen. It shows a diversity of actions where different types of behavior are needed.

To meet the requirements of believable behaviour and social interaction on one hand, and possible causes of the glass ceiling on the other hand, the following concepts should be captured in the model: For nature the focus will be on 1) *skills*, and 2) *motivation for behaviour*, and for nurture on 3) *social feedback*, and 4) *friendship*. Nurture is a broad concept and an implementation of social groups as a whole is too complex. Therefore only the feedback and friendship, related to social groups and interactions, will be used. Note that no explicit concepts for self-organization are implemented in the model, since this should emerge from the previously mentioned concepts and the interaction between them.

The motivation for these concepts are as follows:

Nature

1. **Motivation** A common assumption is that women have a slightly higher need for social interaction. In order to study the influence of a difference in social needs, the agent in the model will have a need for social interaction too. In other words, in some situations an agent's highest priority should be communicating or working together with other agents. Besides acting social, agents also need other drives for action or behaviour. At the same time the action choosing in general should be done in a believable way, i.e. similar to how human choose actions.

2. **Skills** As mentioned before, only small differences can be found in newborns [9]. However, the social interaction can make that these differences are amplified. In order to study this, the agents in the model will have some sort of skill too that they need for the performance of actions. Only then the influence of one group of agents having a higher skill than the other group on the population can be studied.

Nurture

1. **Social feedback:** In a social environment people continuously interact with each other. This can be straightforward by chatting, but also less directly by non-verbal gestures. If indeed women have a higher need for and are more sensitive to social interaction, this continuous verbal/non-verbal

interaction can influence their behaviour. Moreover can it influence the type of people they want to have around them. By choosing a social environment where one is at ease different social groups can emerge. In order to study the effect of the continuous social interaction, the model needs a concept too that this. Therefore the concept of so-called social feedback will be introduced, where agents continuously give feedback towards each other about each other's behaviour. This feedback will be a subjective evaluation of others' behaviour, i.e. will depend on the state of the agent that gives the feedback.

2. **Friendships:** The mutual relationships between people make that one has a certain attitude towards another, which can be friendly or hostile, based on prejudices or experience. The attitude changes over time, depending on number and type of interactions. This can have an influence on the emergence of the glass ceiling in two ways. First of all, if children learn that there is a difference between the two sexes, these prejudices can make that they act differently towards children with the same sex than to children with the opposite sex. Secondly, getting to know somebody and liking that person, depend on each others' needs. If these needs are gender related, this results in friendships between people having the same sex. This intensifies the gap between men and women. In order to test this concept and the influence on the social interaction, the agents will have a so-called friendship attribute towards all other agents. This is a value representing the beliefs about the other, based on both experience and prejudices, and can be positive or negative.

The four given concepts should be implemented in the model, directly by giving the agents a skill value or indirectly by integrating the process of giving feedback in the deliberationloop of the agents. In particular the need-driven behaviour should be in the core of the framework of the agents. Therefore the following theories will be used in the model:

1. **Need theory**: A theory that captures different types of motivations for the behaviour of people is the need theory of McClelland [14]. By implementing this theory in the model the agents will be driven by different needs, namely the need for *achievement*, i.e. having success or achieve certain states, the need for *power*, i.e. getting control, and the need for *affiliation*, i.e. being accepted by others.

2. **Theory of planned behaviour:** In order to have a proper action-planning process, where all four mentioned concepts can be taken into account the theory of planned behaviour from Ajzen [15] will be used. Moreover, it can easily be put together with the need theory, since it is important that the action planning of the agents is driven by their needs.

Research Questions

To study the emergence of social groups, insight is needed on how the four previous given factors, namely skills and motive as nature, and feedback and mutual friendships as nurture, influence interaction or stimulate agents to stay away from each other. In other words, which factors make that agents want to stay together or rather move away from each other, what will result in the emergence of different

groups? In order to study the main question, first the following three sub-problems will be considered and tested with the computational playground:

1. When acting in a group, members influence each other on their goal choice. People will give comments to each other, positive or negative, according to one's own beliefs. For example, a group of boys encourage one friend to talk to a girl. If that friend wants to get approvement of the group, he might go talk to the girl. On the other hand, if that friend is afraid for rejection of the girl, he might get mad at the boys for pushing him too much. In the second example this might result in the boy wanting to find other friends where he has the feeling that his needs are met. Accordinly, people will choose a surrounding where they can satisfy their needs the most.

   The example shows how different types of behavior will influence the emergence of different groups and therefore the influence of the feedback in the model needs to be tested. This is done with following hypothesis:

   Hypothesis 1: The way feedback changes behaviour depends on the motives of both the feedback giver and receiver.

2. In the previous question the effect of feedback on one individual is tested. But what happens when multiple individuals, that all receive feedback from one other are put together? Are there motives that are more likely to interact with each other? Is there a motive that rather isolates from other type of motives? If the latter is the case, this might have an influence on the emergence of the glass ceiling too. Which motives, while giving each other feedback, form a good base for a stable group, and which does not? There the following hypothesis can be formulated:

   Hypothesis 2: Stability of a group depends on the motives of the members of the group.

3. Consider the situation of children wanting to play some football. Their motivation of why they want to play football can be different. Some of them are just happy playing the game because of a friendly activity, others will be disappointed because they lost the match. This difference in interest and motivation to do something results in different personal opinions towards each other. Particulary for the affiliate it can be a disappointing game, since he can be blamed for not playing well enough and therefore losing the game. The effect on the emergence of the glass ceiling is that not a difference in expertise but in interests would make that some like playing the game together and other do not. However, if the affiliate would be great football players, they would be able to help the needs of the others, and in return would get the feeling of acceptance. To study the influence of these nature effects, the following hypothesis is tested:

   Hypothesis 3: While playing football, agents high on affiliation will have better mutual relationships with other agents if they have relatively higher football skills.

The rest of the thesis will be as follows: In chapter 2 the theoretical background is discussed. Besides related work the need theory will be explained in more detail. Also the theory of planned behaviour is discussed. Then, in chapter 3, the model with both the Need theory and theory of planned behaviour

integrated will be shown. The use of the model in the computational playground will be discussed in chapter 4. The results of the hypotheses is shown in chapter 5 and an answer to the main question is given, and finally, in chapter 6, some issues will be discussed, together with future work. The conclusion of the thesis is given in chapter 7.

Chapter 2

Theoretical Background

In this chapter the theoretical background is explained. In the first section related literature is discussed with models that use need-driven agents. As mentioned in the introduction, the need-driven behavior should be the core of the framework. Although self-motivated agents are now a common field of research within artificial intelligence, it is still relatively recent [16]. Some recent models using these type of agents will be discussed. Secondly, the need theory itself is explained and characteristic behavior related to the different motives are discussed. Finally, in the third section, the theory of planned behavior is explained and it is argued why this theory is useful in the combination with the need theory.

2.1 Related Work

2.1.1 BDI model

The creation of the belief, desire and intention (BDI) agents [17] can be seen as a first step towards so-called autonomous agents with a decision-making process that is similar to human reasoning. The model could also be linked to the need theory with motives. As stated in [18] the agents have an achievement related motive, where they try to reach a certain goal state. However, the BDI model still lacks real believable behavior. First of all, the process of reasoning is quite rational in contrast with human reasoning. Furthermore, besides achieving states, people also have the drive for control and affiliation. Although the BDI model has some extensions where social interaction is taken into account [19], it has no social layer in the core of the agents [20]. In [20] a new framework, aside of the BDI framework, is proposed for real social agents.

2.1.2 PSI model

The PSI model [21] is a model where emotions, drives (or needs) and motivation come together. The three needs as described in the need theory are also used in the PSI model: affiliation, uncertainty for power, and competence for achievement. Besides these need also more primary needs, like hunger and

sleep are used. The needs are visualized by tanks with water. The tanks empties due to several factors, like energy-use. The water level should be at a certain threshold, called set-point, and a deviation from this set-point leads to a need for filling the water tank again. The water level increases by performing actions for that specific need. The example is given that going to the bakery will increase the water level of the tank representing hunger. In [22] a computational architecture of the PSI theory is presented and in [23] this architecture is applied. An artificial society of mice was simulated and the emergent behavior after overcrowding was being studied. The actions of the mice were regulated by the cognitive system as in the PSI model, driven by motives and needs.

The mechanism that represents the needs and motives shows similarities with the model of McClelland. However, in the PSI model no emphasize is put on the differences between personalities, i.e. one person has more achievement need than another person. Secondly, the social concepts like friendship and social feedback are not integrated in the PSI model. Affiliation is a drive for "signs of legitimacy" [23], but there is no framework for how this is influenced by or influences friendships between agents. For example, it is mentioned that the mice can become friends in order to help each other in dangerous situations. However, people have an affiliate need and will become friends with others, just for a social interaction. Also the social feedback, which is an interaction based on motives, action and performance, is not taken into account. Both concepts are important in order to study the emergence of social behavior and social groups.

2.1.3 ORIENT

In [24] the PSI model is combined with the FAtiMA architecture [25]; an architecture where emotions are combined with personality in agents. Those agents are used in learning games for children. The proposed model ORIENT, a combination of the needs and drives of the PSI model with FAtiMA, gives rise to a so-called affective autonomous Non Player Character (NPC). The goal of this research was to create agents that could be used in serious games and for educational applications. However, in this thesis a framework for agents is needed that can be used in a MABS. Furthermore, although the agents from ORIENT showed social behavior in the sense that they are able to perform believable interaction, these types of interaction are not necessary in the current model. Rather a framework is needed where agents are able to build a friendship with each other on the long run, where the friendship values are only a representation of virtual social interactions.

2.1.4 Needs and risks

In [16] a model is proposed where artificial agents choose goals driven by an achievement motive as in the need theory by implementing the risk-taking model of Atkinson [26]. This model combines motive, probability of success of an action, and incentive of that action to predict the likelihood of choosing an action. In [27] the model with achievement driven agents is extended with also the power and affiliation motive.

Although the results meet the expectations of the risk-taking model, some comments can be made. One important aspect is the micro versus macro level behavior. The way the goal choosing is implemented is indeed similar to human decision making, but the core of the process is based on observations from the outside. It does not give any inside in the way people themselves choose their behavior.

2.1.5 Power-driven agents

In [28] a multi-agent based model is described that simulates the decision making of consumers. The agents are driven by two main needs: social status and social responsibility and are related to the power distance dimension in cultures.

These needs can be linked to the power motive as in the need theory, but the model lacks the need for affiliation, in order to let the agents seek for social interaction. Furthermore, the status is indeed a social related concept, but is not within the scope or this thesis.

2.2 Need Theory

Motivation is what moves people to do something [29]. Basically, motivation answers the question of why someone chooses to do a certain task. Not only can the amount of motivation differ among people, also the orientation, or type, of motivation can be different while performing the same action. For example, going to a party to socialize or to show others your new outfit are different reasons to go to the same place. The need theory of McCllelland [14] is a model where a distinction is made between three basic needs that can be found in people: the need for achievement, for power and for affiliation. McClelland argues that these needs are culture independent and evolve during the human personal development. Every person has a different combination of intensities of these needs, which makes that people have different 'motivational profiles'.

The need theory is less known than the hierarchy of needs of Maslow [30]. The theory of Maslow argues that within the hierarchy primary needs like hunger and sleep should be met before others higher order needs, like having self-esteem. Although this model also captures social aspects, it is more focused on survival like behavior. Since this is not the case in the research of this thesis, the hierarchy of needs is not relevant for this study.

The needs as in the need theory are related to intrinsic motivation. It means that the reason for action comes from inside and not from an external reward. For example, a student wants to get a high grade for his test in order to proof to himself he understands the course, or because his parents promised him money if his grade is high enough. The first case is an example of an intrinsic motivation, where the need to study comes from one's own motivation. In the second situation the motivation was external, since the student chooses to study not for himself, but for the money he might get afterwards. The rest of this section is split in four subsections. The first subsection is used to explain how the motives drive behavior according to the need theory. Also a cognitive model is given. The other three subsections are dedicated to the three motives and their behavioral characteristics.

2.2.1 How motives and needs drive behavior

The concept of the need theory can best be explained using a metaphor, inspired by the tank example from [23]. A motive can be seen as a bucket with water. Over time the bucket empties. The objective of people's behaviour is to keep the water level in the bucket as high as possible by performing actions. In general, the lower the water level, the higher the need to fill the bucket. For example, when the affiliate bucket is almost empty, i.e. the need for affiliation is high, talking to a friend causes the water bucket to fill again. On the other hand, isolating oneself or interacting with hostile person can cause the bucket to empty only more. Every person has three buckets, representing the motive achievement, power and affiliation. All three buckets should have water as much as possible in order to feel happy. However, one action might increase the water level of the achievement bucket, but lower that of the affiliation bucket. Therefore in general the size of the buckets are not the same.

An import aspect in the need theory is the fact that each person has three buckets with different sizes. If both the power and the achievement bucket are almost empty, filling the bucket with the biggest size has a higher priority.

Now the behavior is driven by two factors: the size and the water level. On hand hand, the bigger the size, the more actions should be performed for this bucket. On the other hand, the lower the water level in that bucket, the higher the need to perform actions in that domain. According to [14] the combination of these two factors form the main drive for behavior. In other words, both the size and the water level give people motivation to do something.

This is all visualized in figure 2.1. With this metaphor the main concepts of the need theory is easy to explain. The size of the bucket is the *motive* of people. This motive value can change over time, but is more or less fixed. Every person has a different combination of motive values, what partly makes that people behave differently.

The water level itself can be seen as a measure of satisfaction. Then 1 - water level is the *need* for performing in that particular domain, i.e. doing actions to achieve, feel powerful or be social. This value of satisfaction or need is more dynamical than the motives. First of all, it changes after every action. The consequences of behavior result in a change of the level of satisfactory. Secondly, which is kind of intuitive, this satisfaction level decreases constantly over time. A positive result will not last forever. It makes that people have to keep performing actions in order to keep feeling satisfied over time.

The combination of the motive and the need makes the *motivation* for certain action. It is not just the needs, or just the motives that is responsible for it. For instance, somebody has not had success for a long time, i.e. his need for achievement is high. However, his achievement motive is low, which makes that he does not care about the lack of success. Therefore his motivation for doing something to have success will be low too. On the other hand, one's affiliation value can be very high, but if the need for affiliation is not that high at the moment, the motivation for acting social will not be high either. In figure (2.2) the cognitive model of the need theory is showed. The motivation that drives people

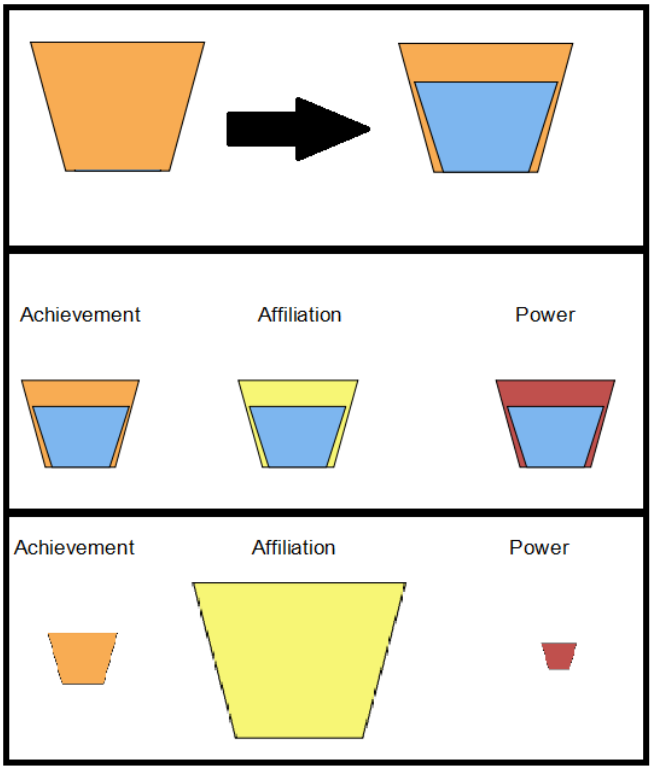


FIGURE 2.1: *Need theory explained by buckets with water. Top: The water level in the bucket needs to be kept as high as possible by performing actions. Middle: For every motive, people have a bucket. Bottom: The size of the bucket can differ for each motive. The size of the bucket is the motive, 1 - water level is the need, and the combination of the size of the bucket and the need is the motivation to take action.*

to take certain action is a combination of the motives and needs. The incentives are the outcome of actions that satisfy the needs, for instance having a social interaction when going to a party.

The motivation together with the believe about one's skills and the importance of performing that action makes the impulse to act. In the case of multiple actions, the action with the highest impulse will have priority. The cognitive interpretation makes that the same action can be evaluated different by two people. For example, two people want to go to a party, but one of them likes the social interaction and the other one is disappointed because no one wanted to listen to him about his new job.

In the rest of this section will be used to explain the three motives in more detail and the behavioral characteristics will be given.

2.2.2 Achievement

People with a high achievement motive want to achieve goals. The nature of these goals can be both practical and social related [20]. For instance making a puzzle successfully or, more socially, getting a reputation in a group [18]. According to [14] only accomplishing goals is not enough, but doing better every time is an important aspect of the achievement motive.

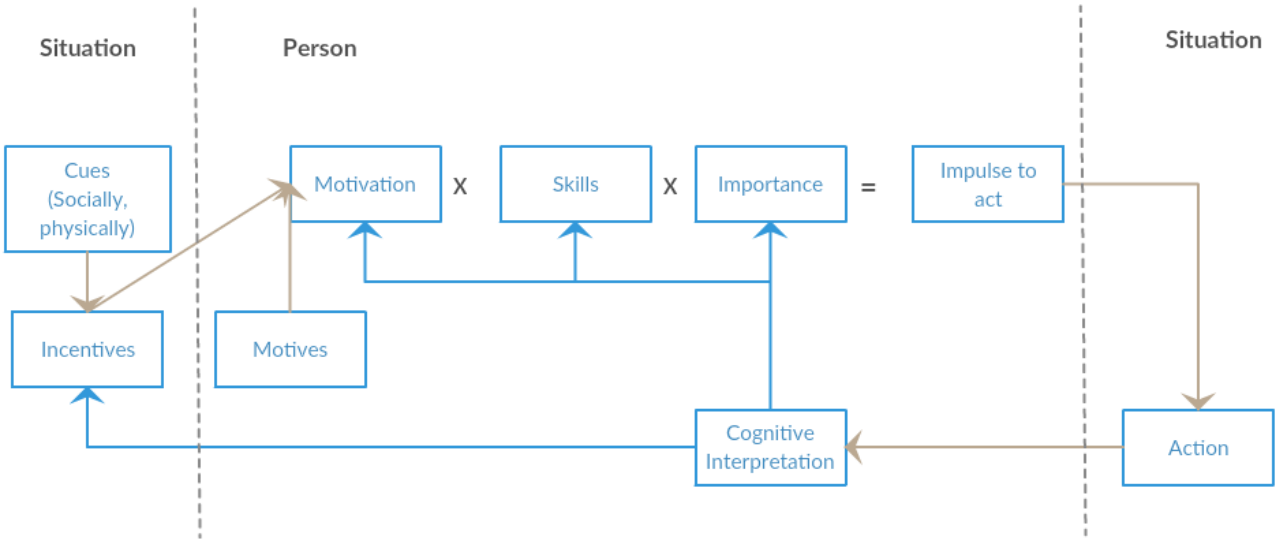


FIGURE 2.2: *Action choosing driven by needs and motives, according to the Need theory [14]*

This motive influences performance of people in several ways [14]. First of all, they are focused on doing things on their own, and therefore focus less on others. Furthermore, because they strive to get better all the time, the achievement motive is also called the efficiency motive. By setting higher goals every time they keep looking for new challenges. They also need feedback of others , in order to know how well they did on their performance.

Research has been done to describe the behavior of people high on achievement. The risk taking model of Atkinson [26] describes how these people choose their actions, i.e. how strong their tendency is to do a certain task. The prediction is based on the motive to achieve, the probably of succeeding in the task and the incentive value of the task, i.e. the personal evaluation of success. This incentive value can be written as 1 - the probability of success, which means that the easier the goal, the less the feeling of success will be. The model describes a parabolic function, where is shown that the most preferred actions are the ones with a moderate difficulty. When an action is perceived as being too easy, the feeling of success is low. After all, it was an easy task. On the other hand, when an action is perceived as being too hard and is performed successfully, it can be seen as just having luck and not using one's own skills. Therefore, people high on achievement prefer actions with moderate difficulty.

2.2.3 Power

People high on the need of power want to have control such that they have an impact on the environment [18]. According to [14] the need for power over resources can be driven by two different intrinsic motives. On one hand, one might want to control or change the behavior of the other resource, which can be people or institutions. On the other hand, wanting to control resources for one own's sake [31] can be the drive. However, in both cases the need for control is the same.

In [31] a distinction is made between six different kinds of power. In all cases explained below person A is the power beholder and person B is the resource, i.e. the one being controlled:

- Reward power: Person A has the authority to reward person B in case of certain behavior. Both person A and B can benefit from this behavior. An example might be a teacher, as person A, and a student, being person B.
- Coercive power: Person A has the authority to punish person B. Same as reward power, but then in a negative way. The coercion is about taking away person B's freedom by threatening with punishments.
- Legitimate power: This kind of power of person A is provided by norms to which person B complies. Person A has the authority to make sure that person B complies to these norms. The difference with the previous two kinds of power is that here the norms are internalized by person B.
- Referent power: Person B wants to be like person A, which gives person A the power to let B behave in a desired way.
- Expert power: Person A has more knowledge or better expertise than person B. This is about domain-specific abilities. In order words, in different situations person B might be the person that has power over person A, as long as person B has better skills in that particular domain.
- Informational power: Person A has the ability to inform person B, which makes person B rethink his behavior and the corresponding consequences.

Like with the achievement motive, models are constructed that explain the behavior of power motivated people. There is evidence that power behavior can be modeled only by risk, not by the incentives and probability of success [31].

According to [32] the social environment can also be important for people high on power. When choosing between tasks with different difficulty levels, they did not show any preference when no other people where around. On the other hand, when playing a game of roulette in public, where only luck plays a role for the outcome, people high in power tended to bet on high risky outcomes. Although they lost a lot, the preference for these risky goals show that those people wanted to impress the others with their feeling of having control on the environment, even though they had no actual control at all.

2.2.4 Affiliation

The third motive is about being liked by others and maintain a relationship [31]. This means that, in order to fulfill this need, an interaction needs to take place. The person who seeks this contact is called the affiliate-seeker and the other person the affiliate and "through the eyes of the affiliation-seeker, the goal of the affiliation is acceptance by the affiliate, to be amiably confirmed, to be appreciated" [31].This can be by direct interaction, like chatting, or indirect interaction, like communicating while working together on a task [33]. Because people high on affiliate do not like competitive situations and are afraid of failing in front of their friends, they tend to avoid high risk goals.

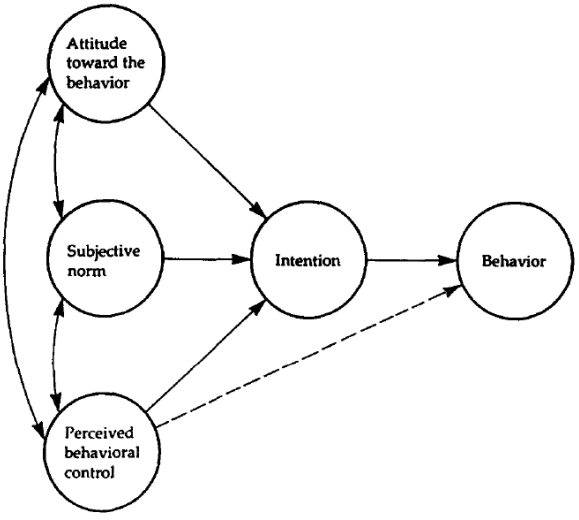
2.3 Theory of Planned Behavior

The theory of planned behavior (TPB) "is a theory designed to predict and explain human behavior in specific contexts."[15] In an environment where multiple actions can be chosen, the TPB argues that for each action a *behavioral intention (BI)* can be made. This intention indicates to which extend an action is likely to be performed. In other words, the behavior with the highest BI will be chosen.

The BI is purely subjective and is the sum of three components that each captures one aspect of the potential behavior. These components are 1) the *attitude towards behavior, (ATB)*, about the consequences of performing that action, 2) the *subjective norms*, concerning the opinion of others about one doing that action, and 3) the *perceived behavioral control (PBC)*, which is the belief of one's own ability to perform the action successfully. The BI then is simply computed by BI = ATB + SN + PBC.

A visualization of the theory can be found in 2.3. The three components ATB, SN and PBC together form a behavioral intention. From all possibilities one will choose that action that has the highest BI, and therefore the most positive prospects. The line from PBC to action is drawn, because the PBC not only influences the action indirectly by predicting one's own ability, it has also an influence while performing the action itself. Just having the right skills and knowledge is not enough to succeed, one should also believe in it.

The rest of this section is used to explain the three components that form the BI in more detail. It is showed how all the components can be split in two parts: An objective aspect, i.e. what is a possible outcome or what is a possible response of others, and a subjective aspect, i.e. how much do I want that outcome or how much do I care about that response. Throughout the section an example is used, about a student considering studying the whole weekend, in order to get more insight on how the TPB works. Then the computation of the BI is shown and how this creates action choosing. Finally, some critics about the theory are discussed and why it is still useful for the proposed model.



[34]

FIGURE 2.3: Schematic overview of the theory of planned behavior

2.3.1 Attitude Towards Behavior

The ATB is an prediction about the consequences of the behavior. It is the sum of all possible outcomes where the belief of that outcome is multiplied with a subjective evaluation about that outcome. The ATB, then, is proportional to the sum of all outcomes, i.e.:

$$\text{ATB} \propto \sum_{i=1}^{n} b_i \times e_i, \tag{2.1}$$

with i each possible outcome, b_i the belief about that outcome and e_i the evaluation of that outcome. In order to better understand the ATB, it will be computed for the student that needs to study. He is considering the behavior of studying the whole weekend. Possible outcomes of that behavior is that a) he will miss the party on Saturday night and b) he might pass the exam. Missing the party he knows for sure, so his belief about missing the party is high. His subjective evaluation about missing the party is very negative, since he likes to go out with his friends. He is not sure about passing the exam, so this belief is not as high as the one of missing the party. On the other hand, he really wants to pass the exam, which makes that the subjective evaluation of it is high. Translating these findings into numbers, with 1 very likely or 0 almost impossible, and 1 desirable, and -1 not desirable, the ATB for studying the whole weekend could be:

$$\text{ATB(Studying)} = b_{\text{Missing Party}} \times e_{\text{Missing Party}} + b_{\text{Passing exam}} \times e_{\text{Passing exam}} = 1 \times -0.5 + 0.8 \times 1 = 0.3$$

. Since this is a positive value, purely based on the ATB the student might consider to study afterall.

2.3.2 Subjective Norms

The subjective norms are about behavioral rules from the social environment. Those norms are linked to people or institutions. With this term in the BI, social impacts are taken into account when considering behavior. Violating a norm is not illegal, but it might be frowned upon. Choosing certain behavior might cause the people that mandate norms to be rewarding or punishing.

The SN is again a combination of the belief of that this rewarding or punishment takes place and the commitment towards the norm or person that mandates that norm, i.e. how much does one care about a punishment or reward for violating or complying to this norm.

Like with the ATB, the SN is computed by taking the sum of all possible norms that are related to performing action i, multiplied with the commitment towards that norm:

$$SN \propto \sum_{i=1}^{n} n_i m_i, \tag{2.2}$$

with n the strength of the normative belief, and m a person's motivation to comply with that norm. To make it more clear, take again the example of the student. With his friends it is common to go out on Friday, which he now has to cancel. He knows his friends will not be happy about that, but maybe

they understand that he wants to study. Since they are his best friends, he cares about their opinion. On the other hand, his parents expect him to study for his exam and he does not want to disappoint them with a low grade.

2.3.3 Perceived Behavioral Control

The PBC is about one's belief about performing the behavior successfully and takes all possible resources or opportunities that help performing the behavior in consideration. It is computed by a combination of the subjective control belief times the power of the resource. In order words, how convinced one is that this resource will improve the behavior times the impact that this resource will have on having success:

$$PBC \propto \sum_{i=1}^{n} c_i p_i. \tag{2.3}$$

The perceived behavioral control is comparable to the self-efficacy from the self-efficacy theory [35]. It is proven that the self-efficacy plays an important role not only in creating an intention towards an action, but also in the performance itself. The self-efficacy should not be confused with self-esteem. Self-esteem is a general feeling about oneself, while self-efficacy is about the belief in doing something properly. This means that the self-esteem of a person can be high, as in he is self confident, but his self-efficacy about playing basketball can be really low, because he lacks skills for that.

The control beliefs used for computing the PBC are according to [35] influenced mainly by four factors:

- **Previous experiences** This is the most important factor. When one has been successful before, he will know that in the future he might have success again. The opposite ofcourse also works, that if someone fails all the time at a certain task, little chance that in the future he will have success.
- **Persuasiveness of others** When people in one's surrounding encourage certain behavior.
- **Copying of others** The more people perform a specific behavior, others are more likely to do this too.
- **Physiological factors** If somebody is tired or sick, this will have a negative influence on the control belief.

The importance of this self-efficacy is the subjective feeling that people have. Two people with the exact same skills, in other words both would be able to do a task, might feel totally different about it. One of them might have had bad experiences with that task or has some friends saying better not to do that.

Relating the computation of the PBC to the example of the student, he will take all the possible resources into account that help him passing the exam. Having the right study materials and a quiet place to study, for instance, are relevant resources. The related beliefs are based on the four factors

pointed out above. For example, he is tired but at the same time he knows from experience that a weekend full of studying will make him pass the exam.

2.3.4 Critics

Two main critics can be made about the theory of planned behavior. First of all, in the example of the student the numeric outcome of the BI of studying might be equal to 1.32. At the same time, the BI of not studying might be equal to 1.33. This means that there would be a slight preference towards not studying. However, it is hard to imagine that people plan actions and weigh options in this numerical way. However, for this computational model it is still a useful theory. It serves a good mathematical foundation to bring together different influences that act on action choosing. At the same time the ATB, where different consequences of behavior are considered, is an proper concept in which the needs from the need theory can be integrated.

A second critic about the TPB is the lack of influence of past behavior [36]. According to around 13% of variance in behavior can be explained by past behavior. This means that sometimes people do actions, because they are used to do actions, regardless of they like the outcome or think they are good at it. These habits make that before taking an action not all possibilities need to be considered. Using the TPB in a complex dynamic environment would make decision-making impossible. Although this critics is legit, the TPB is still useful for modeling the playground. The critics given cover a long term aspect, where people do the same things for a long time. In the playground example the time span is not about years, but more about hours or days. Furthermore, habits might make that the glass ceiling emerges, so also the formation of these habits is what needs to be studied. Therefore they should not already be captured in the action planning.

Chapter 3

The Model

In this chapter the computational framework for the playground is explained. It is given in a general way such that it can be used for the playground simulation, but at the same time also for different computational applications.

The core of the model is the need theory, which drives the agents to choose actions and makes them behave in different ways. As mentioned in the introduction, the influence of agents having different motives on group emergence will be studied. In the first section is explained how the need theory is used in the computational model. Accordingly, the agents need a framework such they behave according to the need theory and this framework is shown in section 2. It is also showed how the concepts as skills and friendships are integrated in the framework. In the third and final section the deliberation loop of the agents is explained. It shows how agents choose actions, according to the TPB, and in what way the agents have an influences on their performance. Also the social interaction, i.e. giving feedback and building relationships, is integrated here and it is explained how these nurture related concepts can be used by the agents.

3.1 Use of Need theory

This section will be used to explain the implementation of the need theory as explained in section 2.2. First of all, the three motives are expressed in one simple behavioral rule each where agents can focus on. Secondly, a measure is needed that expresses the needs of the agents that drives their behavior. Therefore a *well-being attribute* is introduced. It can be compared to the water level inside the buckets, according to the example explained in section 2.2. From that well-being value the need value can be computed. Now the drive for the agents' behavior is to keep the well-being as high as possible, i.e. the need as low as possible, by performing actions. In the model each action has an outcome that exists out of three directions. Each direction corresponds to a specific result that satisfies one of the needs. For achievement the *competence* matters, for power the *control*, and for affiliation the *acceptance*. Then, finally, the formula for motivation is given, that is simply a combination of the motives and needs.

3.1.1 Motives

Although multiple characteristics related to the motives are given in the literature, each motive in the model is a simple rule. These rules are basically a different approach of looking at the outcome after every action.

Achievement

The achievement motive is the motive that can be compared to the motive of agents in the BDI model [18]. It is the motive about successfully performing an action or reaching a goal. This is also how achievement is interpreted in this model. After every action the agent evaluates his competence for his achievement need, which comes down to evaluating if he had performed the action successfully or not.

Power

As mentioned in section 2.2.3, someone who is high on power wants to have control in the environment. In the model this is interpreted as learning and increasing one's skills, since high skills give more certainty in performing. This kind of power is comparable with the expert power, as mentioned in section 2.2.3. It is also the kind of power without another person involved and a person wants to have control for his own sake. After every action the agent evaluates how much his skill increased by his performance.

Affiliation

Agents high on affiliation want to be accepted by other agents, i.e. getting a positive response when asking to work together. Here the agent evaluates if the interaction with other agents was positive.

In [31] both affiliate and affiliate seeker are mentioned, where they assume that both of them are looking for social contact. However, in the model the affiliate seeker can also interact with an agent that needs the affiliate seeker, for example, for success, rather than being satisfied socially.

3.1.2 Well-Being

The well-being attribute is the concretisation of the need. The main drive for the agents is keeping that well-being as high as possible and for each of the three needs a separate well-being value is needed. The well-being that corresponds to the achievement motive is the competence, for power this is control, and for affiliation this is acceptance. With actions the agents are able to increase the well-being. It is possible that one action makes that the well-being on competence increases, but the well-being on acceptance decreases. In the model, the well-being is a continuous variable between 0 and 1. If one of the well-being values is 0, this can be seen as the agent being 'depressed' in that particular direction.

A value of 1 can be seen as completely happy. After every action the well-being is updated, where a negative outcome leads to a decrease and a positive outcome to an increase of the well-being. :

$$wb_t^u = u_t \times \text{MOT}_u, \tag{3.1}$$

with $u \in \{com, con, acc\}$ and MOT_u the corresponding motive value in dimension u. The totals on these three variables represent the well-being in that specific domain. The overall well-being wb will be given by a three vector, i.e. $(wb_{com}, wb_{con}, wb_{acc})$, which stand for the well-being on competence, control and acceptance respectively.

After each action that well-being is updated in a aggregate way. However, in order to keep the well-being between 0 and 1, a logistic function is used, i.e. $1/(1+\exp(-x))$, the total value in competence, control and acceptance respectively. Then wb^u at time t can be computed by:

$$wb_t^u = \frac{1}{1+\exp(-\Delta_t^u) \times (\frac{1}{wb_{t-1}^u} - 1)}. \tag{3.2}$$

The fraction in the denominator is the inverse of the well-being value of $t-1$, such that the gain or loss after the action can be added before it is scaled back to a value between 0 and 1. The overall well-being wb_t at time t is given by the vector:

$$wb_t = (wb_t^{com}, wb_t^{con}, wb_t^{acc}) \tag{3.3}$$

Decay Value

According to the explanation of the need theory in section 2.2, the well-being of the agents should decrease over time, independent of the actions that are taken. Several reasons for this decay in real life can be thought of, like skill decrease because of a lack of practice, or living in isolation for some time. Accordingly, agents need to keep performing in order to let their well-being at the same level. The decay δ of the well-being in the model is a value between 0 and 1 and the decrease takes place at every time step. When $\delta = 0.9$ it means that every after team step only 90% of the well-being value is left over, or as with the buckets, only 90% of the water amount is left compared to one time step before.

Putting the well-being value in formula (3.2), this gives the following formula for the well-being:

$$wb_t^u = \frac{1}{1+\exp(-\Delta wb_t^u) \times (\frac{1}{wb_{t-1}^u \times \delta} - 1)} \tag{3.4}$$

3.1.3 Needs

With the definition of well-being the needs can be defined too. In the model the needs are a function of the well-being, i.e. the lower the well-being in one of the three dimensions, the higher the need to

perform actions that will increase the well-being in that direction. The needs are simply given by:

$$N_t^u = 1 - wb_t^u, \tag{3.5}$$

with $u \in \{com, con, acc\}$.

3.1.4 Motivation

With the motives and needs defined, the motivation for certain behavior can be defined too. As explained in section 2.2 motivation is the combination of the need and the motive. For instance, if both the bucket of achievement and affiliation are for only 20% filled with water, it depends on the size of the bucket how high the motivation is for an action in that direction. In both cases the need is equal to 1 - 0.2 = 0.8. However, if the achievement motive is 0.3 and the affiliation motive 0.9, the motivation for an affiliate related action is higher. Therefore, the motivation MOT_t at time t for behavior in one of the three direction is a combination of the needs given in (3.5) and the motives and is given as a vector:

$$\begin{aligned} \mathrm{MOT}_t &= (\mathrm{MOT}_t^{com}, \mathrm{MOT}_t^{con}, \mathrm{MOT}_t^{acc}) \\ &= (N_t^{com} \times \mathrm{ACH}, N_t^{con} \times \mathrm{POW}, N_t^{acc} \times \mathrm{AFF}). \end{aligned} \tag{3.6}$$

3.2 Agent

As mentioned in the introduction, the framework of the agents should contain skills and friendship and a base for need-driven behavior. Therefore, the following five concepts are the basics of this framework.

1. Motives: The motives of the agents are, in combination with the well-being, the main drive for actions. These values are fixed and represent a personal character for behavior.

2. Well-being: On three different levels the agents can increase their well-being. In contrary to the the motives, these values are continuous and vary over time.

3. Friendships: Towards every other agent a friendshipvalue is contained in the agent itself. It represents the quality of the interaction so far. If no interaction took place, the friendship value represents first impression, that can be positive or negative.

4. Skills: For each action that can be taken the agents use a skill that is needed for that particular action. Those skills develop over time by practice.

5. Memory: The action planning of the agents is done according to the theory of planned behavior. An important concept is the gained knowledge about the actions and outcomes from previous experiences. Therefore, the agents need to be able to store this information.

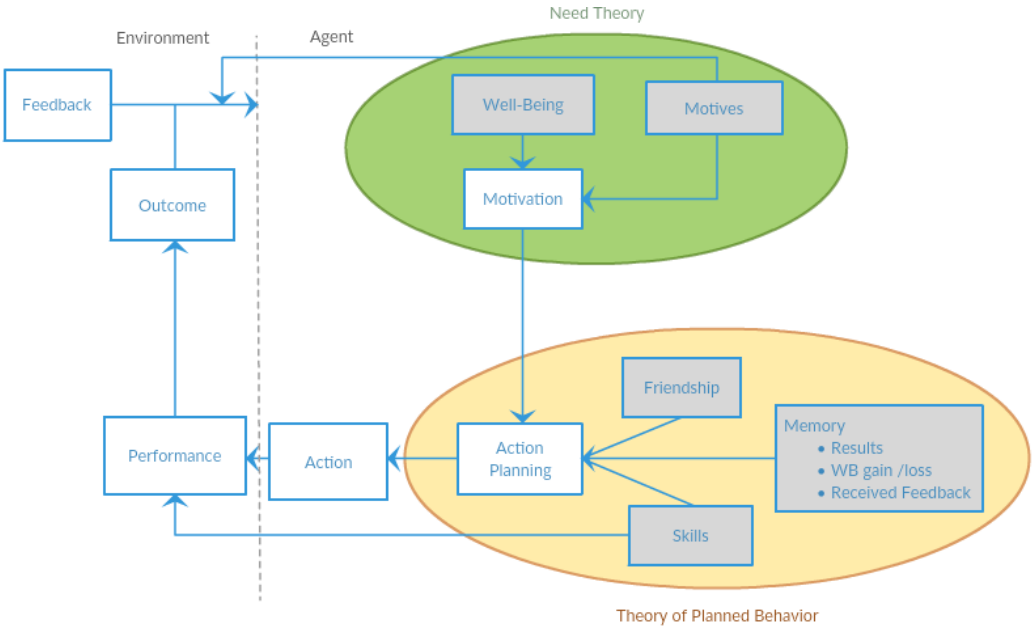


FIGURE 3.1: *An overview of the model where both the need theory and the theory of planned behavior are integrated. The diagram between the green dotted lines expresses the agents' cognition. The gray blocks belong to the architecture of the agent. The motivation is the combination of the needs and motives of the agent. In order to compute the BI of an action the previous experiences are needed, that are based on previous outcomes. In combination with the current skill, friendships, the agent is able to form an ATB and PCB of each action. When an action is chosen, the agent performs that action. Here the environment can influence the performance, for instance by other agents helping. The agent will use the outcome of the action to compare it with his pre-set expectations of the outcome. Together with the received feedback, the agent determines the increase or decrease in well-being by looking at his motive values. After that the friendships and the skills are updated and experiences are stored in the memory. The specific context that led to this increase or decrease, is important for future predictions and is therefore stored in the memory too.*

In 3.2 an overview is showed of how the concepts of the agents are related and influence the action choosing. It visualizes the combination of the need theory, the theory of planned behavior and how these theories are integrated in the agents' framework. The motives and well-being functions are needed in the need theory and are combined for the motivation. The skill values, the memory and friendship are integrated in the theory of planned behavior and together with the motivation form the base for action planning.

Each concept of the agent's framework will be explained in more detail, while using examples related to children playing in the playground.

3.2.1 Motives

All agents have three motive values, which will be a value between 0 and 1. Each agent has a personal (unique) combination of values. For example, agent A has for achievement, power and affiliation the values 0.8, 0.2 and 0.3 resp., while agent B has 0.2, 0.5 and 0.9 resp. This means that agent A is more sensitive for changes in competence (achievement) while agent B will be more sensitive towards social related outcomes (affiliation). If both of the agents choose to play football, the motivation for agent A

will be the winning aspect of football, while agent B prefers football rather for the social aspect, i.e. playing in teams. This is also visualized in figure 3.2.

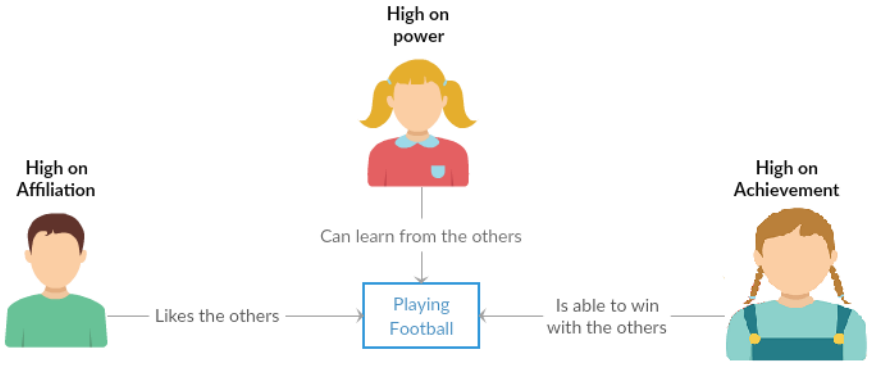


FIGURE 3.2: *Different motivations for playing the same game.*

3.2.2 Well-Being

Each well-being value is influenced by the outcome of the action. For example, in the case of football, the outcome of the match influences the feeling of competence. In case of winning, the competence increases, and in case of loosing, the competence decreases. For control, the agent evaluates his increase in skill, and for affiliation the mutual relations between the agents is taken into account.

3.2.3 Skills

For each type of action that is possible in the model the agents have a corresponding skill. In a playground with football and rope skipping, the agents have a football skill and a skip rope skill. While the agents perform actions their skill values will increase. The increase will depend on the effort that the agent used in his performance and his current skill value. However, the increase will not depend on success or failure. This can be interpreted as learning from one's own mistakes and fail ten times before succeeding. For instance with rope skipping an agent 'learns' the trick, although he fails doing it properly. The skill value is always between 0 and 1, with 0 being unable to do anything in that specific skill domain and 1 being a so-called expert. The increase of the skill is not linear: When someone starts with playing basketball for example, it will take more time and effort to become better in the beginning than later on. Also for an expert it takes more effort to increase the same amount of skill as before. Therefore, the function that is used to update the skill at time t is a logarithmic function, i.e.:

$$s_t(\alpha) = d(\alpha)/(1 + \exp(-k \times e^i_t(total)),$$

with $d(\alpha)$ the difficulty of succeeding in performing action α, k a constant that determines the slope of the function and e^i_{total} a cumulative value with the total effort put in at time t by agent i to increase

skill $s(\alpha)$. This function only increases, but is concave up at the beginning and concave down at the end, which corresponds to the development of a skill as discussed before.

In order to only keep track of the effort put in at time t, and not the cumulative effort until time t, the function can be rewritten into a recursive function. Now it will be a function of effort used at time t and $s_{t-1}(\alpha)$, i.e.:

$$s_t^i(\alpha) = \frac{d \times c}{(1 + exp(-k \times e_t^i) \times (d - s_{t-1}^i)/s_{t-1}^i)}. \tag{3.7}$$

With taking the difficulty of the task in the numerator the function is bounded. Accordingly, the maximum reachable skill value depends on the difficulty. In order words, the agent cannot become an expert when the task is too easy relative to his skill. In the given example of the playground agents develops his skip rope skill less when doing an easy trick, compared to practicing a hard trick.

3.2.4 Friendship

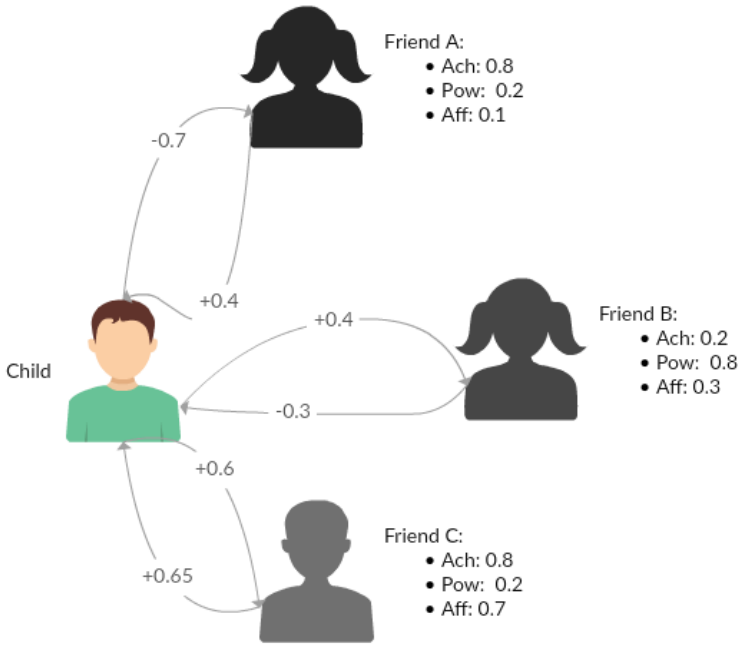


FIGURE 3.3: *Children and their friendships: The picture shows that the friendship is not symmetrical, i.e. one child can feel different towards another (have another quality value towards the other child). The motives play a role here too. For example, friend A has a high achievement motive. It is most likely that her well-being increases because of successful actions. Because friendships get updated based on the gained or lost well-being associated with that friend, friend A likes the child because of successful cooperation. On the other hand, friend B does not like the child. She has a high power motive, so most likely she has the feeling she can not learn anything with or from him. Finally, friend C has both a high achievement and a high affiliation motive. Here it is less obvious why the friendship towards the child is positive. It can be because of successes or because an already positive relationship that keeps increasing.*

The agents are able to become friends and maintain their friendship. This is necessary for the agents in order to decide if another agent is an appropriate partner for interaction. The friendship between two agents depends on previous positive or negative interactions with each other, where the interpretation of these interactions is subjective, and influenced by the motives. For example, when two agents play

football together, with one having a high affiliation motive and the other a high achievement motive, and are defeated, both will evaluate the match, and therefore also the friendship, differently. The agent high on achievement associates the defeat with the other agent, and for him the friendship towards the other will decrease. The affiliate agent on the other hand does not care about the outcome of the match, only for how much he is accepted by the other agent. So if that other agent wanted to play with him in the first place, he will evaluate the game as a positive action and will increse the friendship towards the other.

From this example two important characteristics of the friendship in this model can be obtained. First of all, the friendship is not symmetrical, i.e. one agent can like the other, but not the other way around. Secondly, if two agents like each other, this might be for different reasons. As in the example, agent 1 can like agent 2 because he helped agent 1 to win the match, but agent 2 likes agent 1, because he feels accepted by agent 1. This is also visualized in figure 3.3.

In the model the friendship is represented as a two-dimensional value, with on the first scale the quality of the friendship, which can reach from -1 to +1. This value will be updated according to the gain of loss in well-being. The other scale is the familiarity, which depends on the number of interactions. In the literature it can be found that both aspects of friendship play an important role in social situations [37]. Both concepts will be explained in more detail.

Familiarity

When the familiarity between agent i and j is 0, it means that the agents do not know each other. The quality of the relationship in this case can be seen as a first impression about the other. The higher the familiarity, the better the agents know each other. If the familiarity is equal to 1, the quality can be seen as the value of the friendship.

Quality

The quality part of the friendship is updated in the same manner as the skill in formula (3.7). However, the function is scaled differently, in order to make it range from -1 to 1:

$$q_t^{i \to j} = 1 - 2/(1 + \exp[0.1 + \mathrm{WB}_{\mathrm{TOT}}^{i \to j}]), \tag{3.8}$$

with $\mathrm{WB}_{\mathrm{TOT}}^{i \to j}$ the total well-being gained by agent i while performing with agent j. Therefore, the quality of the relationship is always directed from one agent to another, because the well-being is a (unique) personal value. The reason why the friendship is maintained can vary and also the evaluation of the task by both agents can differ.

Like the skill, the quality of the friendship is updated in a recursive way, where the old friendship value at time $t-1$ and the delta well-being gained at time t is needed:

$$q_t^{i \to j} = 1 - 2/(1 + \exp[0.1 + \mathrm{WB}_t^{i \to j}] \times (1 + q_{t-1}^{i \to j})/(1 - q_{t-1}^{i \to j})), \tag{3.9}$$

3.2.5 Memory

The agent has to store information about his experiences in order to predict future behavior and outcomes. This prediction is needed so that the agent can estimate if and how much his need will be satisfied. Three different types of information are stored:

- Outcome: After every action the agent stores the outcome on competence, control and acceptance.
- Gain in well-being: As with the outcome, the agent stores his gain or loss in well-being. The difference with the outcome is that here the outcome is compared to his expectations and his motives are taken into account. Also the feedback of other agents is included.
- Feedback: Which agents gave what value of feedback during which action.

The gain, or loss, in well-being is stored such that the agent knows how much his well-being increased or decreased during previous times, due to his action. Then, every outcome of every action is stored in the agent's memory such that the agent can compute an average outcome, i.e. his expectations, for the next outcome. After performing the action, the outcome is compared to his expectations. Finally, the feedback that is stored is the feedback received by other agents after performing actions. When an agent needs to decide if he wants to perform a certain action, he looks at which other agents are in the surrounding of the area, i.e. the agents that will probably give him feedback afterwards. With his stored information he can predict what feedback he will get. This is relevant, since this feedback will also influence his well-being.

Since many factors influence the outcome of that action and the behavior of the agent, it is important that also the context is stored. For future predictions the agent can take the environment of the situation into account and compare it with previous experiences. For example, when agent i wants to talk to agent j, not only does agent i needs to know how much chatting itself will satisfy his needs, but also how much specifically with agent j? And what do other agents give for feedback when agent i is talking to agent j?

3.3 Deliberation Loop

In the previous sections the use of the need theory in the model is explained and how the architecture of the agents relates to the need-driven decision-making process. In this section the action process of the agents executed at every time step will be discussed in more detail, by explaining the deliberation loop of the agents used in the model. A visualization of the deliberation loop is shown in 3.4. The arrows in blue represent the steps made by the agent itself. The other arrows are updating values or the influence of social interaction that has an effect on the behavior of the agent.

The main loop exists out of the following:

1. Action planning: The motivations as in (3.6) are combined with the theory of planned behavior. Also the stored information of the agent is taken into account.

2. Action choosing: The highest BI value will indicate which action is best to perform.

3. Expectations: The expectations of the outcome will be used after the performance, to compare the expected result with the actual result.

4. Performing: The agent execute his chosen action, where the skills among other things determine the effort. Each action has a difficulty, which depends on the action itself and the environment.

5. Outcome: The outcome of the action is computed in the three dimensions competence, control and acceptance.

6. Feedback: After performing the action the agent receives feedback from the surrounding agents. Therefore, the feedback procedure exists out of two parts: Giving feedback and receiving feedback.

7. Evaluation: The outcome is compared with the expectations of the outcome. The evaluation is then combined with the received feedback from other agents and makes that the well-being will increase or decrease.

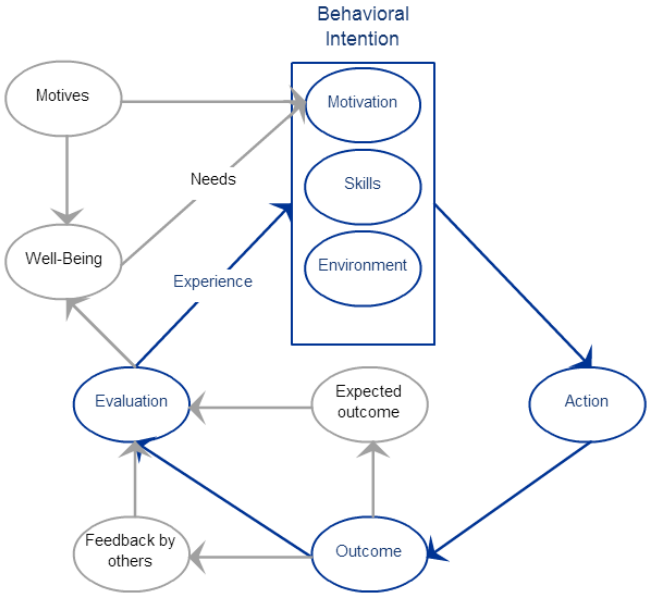


FIGURE 3.4: *The deliberation loop: The main loop of the agents is given by the blue arrows and exists of prediction, action, outcome and evaluation. The deliberation loop starts with the agent setting up the behaviorial intention towards possible actions. Next, the agent will choose the action which the highest BI value and computes his expectations of the outcome of his behaviour. After performing the action and determining the outcome, the evaluation starts. The agent will compare the outcome with his previous made expectations. Both outcome and evaluation of it will stored in memory and used for future action taking. The evaluation together with the received feedback is combined with the motives and will be used for updating the well-being values.*

All steps in the model are the same for every agent, independent of his motive values. Different behaviour is obtained by different motives, beliefs and experiences. The motives for instance are used to weigh each of the three evaluation dimensions.

The rest of this section is used to explain all steps of the deliberation loop in more detail. The description start with the explanation of the action choosing, which is done by the agents right after the action planning, i.e. computing the BI values. Since the computation of the BI values is based on previous experiences gained during the other steps of the deliberation loop, it will be considered at the end of this section.

3.3.1 Action Choosing

After the agent computed the BI towards every possible action, he chooses the action that has the highest BI. It is possible, however, that this action is not executable. Reason for that can be that there is a lack of resources or not enough agents to work with. For example, an agents wants to go rope skipping, but all skip ropes are occupied. When an agent is not able to perform an action his evaluation of this action will be adjusted in a negative way. It means that in the next prediction for behavior this action will be less attractive. For example, if agent i is rejected for an interactive action by agent j, he will update his memory. The loss in well-being because of not performing at all will be stored as result of interacting with agent j. This also influences his quality of relationship towards agent j. Then, when computing the next BI, the BI towards asking agent j for interaction will be lower in both the ATB as the PBC component.

It is also possible that agents choose to not perform any action. They can choose to do nothing, because that seems to be the best option. If all possible action give a negative BI, they better wait until the environment changed in a positive way.

Before starting the actual action, the agent has to set his expectations about the outcome of the action.

3.3.2 Expectations

An important part of the performance evaluation is the expectation that is set before the action [31]. Therefore, this is also taken into account in the model. The expectations are based on the previous experiences, i.e. previous outcomes, of the agents.Because the agents are developing their skills the outcomes will get better over time. This means that relatively old experiences do not give an accurate prediction for the future. That is why only the last experiences are taken into account. Also the expectation $\mathrm{EXP}^i(\alpha)$ of agent i at time t for action α will be a three dimensional vector with the predicted outcome in competence, control and acceptance:

$$\mathrm{EXP}^i_t = 1/n \sum_{k \leq n} \mathrm{OUT}^i_{t_k}(\alpha), \tag{3.10}$$

with n the number of previous experiences taken into account, and $t_k \leq t_n \leq t$ the moments in time that agent i performed action α. If the number of experiences is less than n, only those experiences will be averaged.

Now that the expectations are set, the agent is ready to perform.

3.3.3 Performance

In order to compute the outcome, the difficulty of the action and the effort of the agent is needed. According to [38] the performance is a combination of motivation and ability. In the model the motivation will not be used for the performance, since the agents are not able to set particular goals. Because of the relationship between goals and motivation, it will be irrelevant here.

The ability, i.e. the effort, is the combination of the skill of the agent and the energy put in. The agents do not have a unlimited amount of energy that they can use. They have an maximum energy level E^{total}_{max}. With every action the agents can use a certain amount of 'energy units'. Every time step the energy level is updated by a fixed increase. The energy that an agent can use for the performance, E^{use}, also has a maximum, E^{use}_{max}, such that $E^{use}_{max} \leq E^{total}_{max}$.

Hence, the effort is computed as follows:

$$\text{EFF}^i_t(\alpha) = E^i_t \times s^i_t(\alpha), \tag{3.11}$$

with E^i_t the energy used by the agent.

After the performance the agent needs to compute his outcome, in order to evaluate how his needs are satisfied.

3.3.4 Outcome

The outcome is the three dimensional value that represents the result of the action done by the agents. The way the outcome is computed is different for each of the three dimensions.

Competence

The result of the action is a binary value with 0 standing for failure and 1 for success. In order to determine the outcome of the action a probability is used as in [8]. $P(\text{result} = 1)$ depends on the performance of the agent and the difficulty of the task:

$$p^i_t(\alpha) = \frac{e^i_t}{e^i_t + d(\alpha)}, \tag{3.12}$$

where e is the effort as in [39] and $d(\alpha)$ the difficulty of action α. To determine the success of failure, the equation $p^i_t(\alpha) > rand(0, 1)$ is used. When the equation holds, i.e. the random uniform variable between 0 and 1 is smaller than probability p^i_t, it represents the success of the agent and degree of success $d_s = 1$. On the other hand, d_s will be 0 if the equation does not hold. This random factor represents all kinds of external influences on the performance that can make that an action succeeds or fails.

Control

As mentioned before, control is about learning new skills. Therefore the outcome for control is $\Delta skill(\alpha)$, i.e.:

$$\mathrm{CON}_t^i(\alpha) = (skill_t^i(\alpha) - skill_{t-1}^i(\alpha)). \tag{3.13}$$

Acceptence

When agents perform an action where interaction with other agents takes place, the friendship values form the agents determine the outcome. For example agent i, the affiliate seeker, interacts with agent j, the affiliate, during action α. Agent j will only accept the request if the BI value for this type of interaction with agent i is positive. For agent i this will feel as acceptance. The outcome on acceptence is the quality of the friendship of agent j towards agent i. This value represent the quality of the interaction.

An agent is also able to interact with multiple agents at one time. When a group op agents end up interacting with each other, all friendships are taken into account. However, the value of acceptance will not be proportional to the groups size. In the same amount of time a person will spend less time talking to everybody when in an a large group, compared to being surrounded by only a few people. Therefore, the average is taken of all the relationships. In general, the outcome on acceptance is:

$$\mathrm{ACC}_t^i = 1/|G| \sum_{j \in G} \mathrm{QUAL}_{j \to i}, \tag{3.14}$$

with G the agents that belong to the interaction group. An agent only chooses one other agent to interact with. If that other agent is already planning on working together with a third agent, those three agents form the interaction group. It is possible however, that the first agent has a negative BI towards the third agent. In this way the one on one quality between agent i and j can be positive, but because of this third agent, the outcome of ACC can still be lower or even negative. It can be compared with the situation that one is meeting with a friend, but his annoying girlfriend will also join.

Overall Outcome

With the three outcome components as above, the outcome $\mathrm{OUT}_t^i(\alpha)$ of agent i at time t after performing action α is given again by a three dimensional vector:

$$\mathrm{OUT}_t^i(\alpha) = (\mathrm{COM}_t^i(\alpha) \times w_1, \mathrm{CON}_t^i(\alpha) \times w_2, \mathrm{ACC}_t^i(\alpha) \times w_3). \tag{3.15}$$

The three weight values w_1, w_2 and w_3 are scaling values, in order to make sure that all three outcome components are scaled to the same proportions.

The agent has only considered his performance for computing the outcome. However, the agents that are in the surrounding give also feedback, that influences the final evaluation of the outcome.

3.3.5 Feedback

When an agent performs an action, he will receive feedback form the other agents. Since this is a social aspect, it depends on the affiliate motive of the receiving agent how much effect this has on his well-being. The process of giving feedback exists out of two stages: Giving feedback and receiving feedback. Both stages are explained below.

Giving Feedback

Like all other well-being related actions feedback is also given in the three dimensions of the motives. From each motive point of view the feedback given by agent j will be based on the performance of agent i in action and the own interpretation of agent j of the task or relation with agent i.

- Competence: The feedback for competence is the difference between the performance of agent i and the perceived difficulty of agent j:

$$\mathrm{FB}^{j\to i}_{\mathrm{COM}}(\alpha) = OUT^{i}_{\mathrm{COM}} - (1 - EST^{j}_{d}) \tag{3.16}$$

  In this way agent i gets positive feedback when he has success on something, that is being perceived as something difficult by the feedback giver. If an agents fails at this difficult task, the feedback will be negative but close to 0. For example, agent A has success in his rope skipping activity. Agent B, who gives feedback, thinks this activity has a difficulty value of 1. Now the feedback becomes 1 - (1 - 1) = 1. In case of a failure of agent A, the feedback would be 0 - (1 - 1) = 0. From the point of view of agent B the task was so hard that it is not bad to fail at it. However, if agent B sees it as an easy task, i.e. not challenging, with a difficulty of 0.25, the feedback on competence will then be 1 - (1 - 0.25) = 0.25. If agent A fails at this task, the feedback is 0 - (1 - 0.25) = - 0.75. Since the task was perceived as being easy, agent B gives a high negative value. Note that this feedback is independent of the true difficulty level of the task.

- Control: The agent will compare his own skill that is used for action α value with that of the performing agent, i.e.:

$$\mathrm{FB}^{j\to i}_{\mathrm{CON}}(\alpha) = s^{i}_{t}(\alpha) - s^{j}_{t}(\alpha). \tag{3.17}$$

  By subtracting the two skill values the feedback is positive when agent i has a higher skill than agent j, which can be seen as complimenting on the high skill value. On the other hand, in case of negative feedback, the agent gets a negative response for not being the best.

- Acceptance: Agent j will use the quality of the relationship towards agent i:

$$\mathrm{FB}^{j\to i}_{ACC}(\alpha) = \mathrm{QUAL}_{j\to i}. \tag{3.18}$$

  The feedback on acceptance is independent of the task or skills of the performing agent. By using the quality of the friendship, the feedback giver is always positive about the performance when the performing agent is a good friend. This can be seen as supporting friends on their behavior,

no matter what. On the other hand, the feedback is negative if the performing agent is a bad friend. The feedback on acceptance being negative can be intepret as trash talking or gossiping about the performing agent.

Combining (3.16), (3.17) and (3.18) with the motives of agent j the total feedback given to agent i is computed by:

$$\mathrm{FB}^{j\to i}(\alpha) = \mathrm{FB}^{j\to i}_{\mathrm{COM}}(\alpha) \times \mathrm{ACHIE}^j + \mathrm{FB}^{j\to i}_{\mathrm{CON}}(\alpha) \times \mathrm{POWER}^j + \mathrm{FB}^{j\to i}_{ACC}(\alpha) \times \mathrm{AFFIL}^j \tag{3.19}$$

Receiving Feedback

In the model the feedback will be seen as an affiliation component, which means that agents that are high on achievement and low on affiliation will care less about the feedback than agents high on both achievement and affiliation. The total feedback of the agent is the total feedback received by the group of agents G_{FB} multiplied with his own affiliation motive, i.e.:

$$\mathrm{FB}^i(\alpha) = \sum j \in G_{\mathrm{FB}} \mathrm{FB}^{j\to i}(\alpha) \times \mathrm{AFF}_i. \tag{3.20}$$

The agent only receives one value representing the feedback. It is not traceable anymore why this feedback is positive or negative and the motives from the agents who give the feedback are not known either. So for example, a child is playing football. He is being cheered by the supporters. Although the supporters are sending positive signals, for the player it is not clear if they do that because he is playing really well, or simply because they like him.

Before putting all the received feedback together, agent i will store the value in his memory, so that in predicting outcomes he can consider the surrounding agents and the potential feedback he can receive from those. This feedback will be linked to the agent and to the action.

3.3.6 Evaluation

In the evaluation phase the agent combines the computed outcome, his expectations of the outcome and the received feedback. It makes that the evaluation about the outcome is subjective, both influenced by his own expectations and the performance of others.

Since the evaluation of one's own performance is about the absolute outcome, i.e. did the agent have success or failure, learned something, had social interactions, but also about the relative outcome, i.e. how well did the agent perform in comparison with his expectations of his own performance, the evaluation is about both. For all three motives this formula will be the same:

$$\mathbf{eval}^i_t(\alpha) = [\mathbf{outcome}^i_t(\alpha) - \mathbf{expect}^i_t(\alpha)] + \mathbf{outcome}^i_t(\alpha), \tag{3.21}$$

with $\mathbf{expect}^i_t(\alpha)$ is as in (3.10). The part between the square brackets is the relative part of the evaluation since it is compared with the expectations set before.

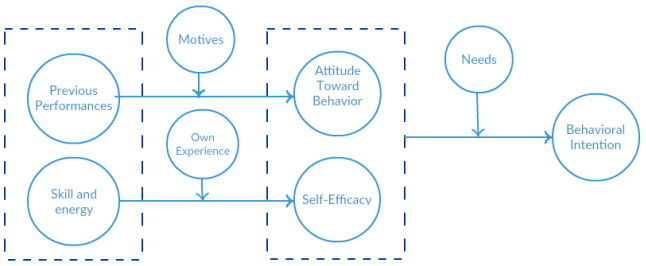


FIGURE 3.5: *The theory of planned behavior as it is used in the model. Previous gains and losses in competence, control and acceptance are combined with the motives and form the ATB. The skill and energy of the agent combined with previous experiences and future predictions are combined to compute the self-efficacy. Finally, multiplying with the needs of the agent the BI is computed.*

After computing the evaluation these values are multiplied with the motives, which is the gained or lost well-being because of the action. These vector is again stored in the memory, and linked to the action. Finally, the agent will use this value to update his well-being. After this step, a new action planning will be performed where all previous collected information of the action is taken into account.

3.3.7 Action Planning

The theory of planned behavior (TPB) is used to let the agents compute a numerical intention toward every possible action. Only the attitude towards behavior and perceived behavioral control are used, because on norms and commitment are not taken into account in the model. In figure 3.3.7 a visualization of the use of the TPB in combination with the need theory is shown.

Attitude Towards Behavior

As explained in section 2.3 ATB is the sum over all possible outcomes where the belief of the occurrence and the evaluation of that outcome are taken into account. In this model not the outcome but the evaluation of the outcome directly is used, because this is a combination of the outcome and the motives. This means that the ATB is expressed by the expected gain or loss in well-being, i.e. delta well-being (δWB), which is based on previous gains or losses. The average delta well-being will be used from the last n trials of the task. In this way experiences from a long time cannot influence current decisions anymore. The formula for computing the ATB becomes:

$$\Delta \bar{WB}_t(\alpha) = 1/n \sum_{k \leq n} \Delta WB_{t_k}(\alpha), \tag{3.22}$$

with $t_k, k \leq n, t_k < t$ the n moments before the current time that the agent performed α. Since ΔWB is given by a three dimensional vector, also the ATB is computed for all three dimensions. Therefore, the ATB for competence can be really high, although the ATB for acceptance is really low. For instance, an agent knows from previous experiences that rope skipping is something that is done alone. Therefore, his delta well-being on acceptance will be 0. At the same time he knows that he liked learning new tricks the previous times, so that his delta well-being on control is positive.

According to the TPB the prospective outcome should be multiplied by the evaluation of that outcome, which in this model would be the motives, i.e. how much does he care for this outcome. However, as given in (3.1) the well-being is already composed out of competence, control and acceptance multiplied by its corresponding motive. Therefore, no extra multiplication with the motive is needed.

Because the agents get feedback from each other, this is taken into consideration too when computing the ATB. This potential feedback FB_{POT} for performing action α is computed by using the group of agents G present at the moment of computing the ATB. Previous given feedback is used to compute the estimation, i.e.:

$$\text{FB-POT}_t^i(\alpha) = \sum_{j \in G} 1/n \sum_{k \leq n} FB_{t_k}^{j \to i}, \tag{3.23}$$

with n as in (3.22), i.e. the n previous times that agent j gave feedback to agent i performing action α. Since this is a prediction, the actual group G that will give feedback might have changed. The way G is chosen depends on the context. For example, it can be all the agents watching the football match or all rope skipping agents giving each other feedback.

Perceived Behavioral Control/Self Efficacy

According to the SET, there are four factors that influence the self-efficacy. In the model, only three of them will be used:

- Previous experiences: Based on how many times the agent succeeded or failed in gaining or losing well-being during the previous task, will give a probability of success.
- Copying of others: Also the experiences of other agents will be used in computing the self-efficacy of one individual. When agents only use their own experiences and own perspective on difficulty, this view might be biased. In order to get a more accurate estimation, the global perspective about the difficulties are used.
- Physiological factors: The agent uses his skill value to predict the outcome. This is the true skill value, and not his belief of his skill value. Besides that, he considers a standard energy level of 2 for the predictions. Later on will be explained how an agent uses energy while performing.

The self-efficacy from [35] tends to focus on only the achievement part of the motives, i.e. considering having success or not. Because there are three needs that need to be satisfied the self-efficacy is extended in such that also the power and affiliation motive are represented. Accordingly, the self-efficacy should be seen as the ability of succeeding in a particular domain. The PBC for the competence is a prediction of the performance, for the control the amount of skill that can be learned and for acceptance the probability of being accepted by another agent. How all of these abilities are computed, is explained below.

- PBC_{COM}: The probability of success when performing action α is needed. This will be based on previous experiences, but also on the skill and the perceived difficulty of the agent. Also the

global perceived difficulty is needed to get an accurate estimation of the difficulty. Furthermore, the skill considered for action α can be increased without performing α itself, which can increase the probability of success.

First of all the estimated difficulty $\text{EST}_d^i(\alpha)$ is computed for every agent by using the inverse formula used with the performance. The skill and the known probability of success are used:

$$\text{EST}_d^i(\alpha) = skill \times 2/P_s - skill \times 2, \tag{3.24}$$

with P_s the observed probability of success of the agent based on previous performances. In order to keep the value of $\text{EST}_d^i(\alpha)$ between 0 and 1, it is transformed by the sigmoid function. The multiplication of 2 with the skill is added, as an average energy input. The reason why not just the probability of success is used, is that the probability also depends on the skill value of the agents. A hard task can be easy for an agent with a high skill, while agents with a low skill value have less success. Their perception of the probability is different.

The global estimated difficulty $\text{EST}_d^{\text{GLOB}}$ can be computed by taking the average of all individual estimated difficulties. Both the individual and the global estimation will be used by the agent to compute the estimated probability of success ($\text{EST}_{P_s}^i$):

$$\text{EST}_{P_s}^i = 2 \times s^i/(2 \times s^i + (\text{EST}_d^i + \text{EST}_d^{\text{GLOB}})/2). \tag{3.25}$$

- PBC_{CON}: For control it is about how much there is left to learn, so the agent will look at the estimated difficulty and his own skill. The estimated difficulty is needed, because this indicates the maximum attainable skill value. The following formula is used:

$$\text{PBC}_{\text{CON}}(\alpha) = \text{EST}_d^i(\alpha) - s_t^i(\alpha). \tag{3.26}$$

- PBC_{ACC}: Finally, if α is a interactive action, the agent should estimate how successful he will be in communicating with other agents. Therefore, the quality of the friendship is taken, because this gives an estimation of being accepted, from the affiliate-seeker point of view:

$$\text{PBC}_{\text{ACC}}(\alpha_j) = QUAL^{i \to j}, \tag{3.27}$$

where α_j stands for the action wherein agent j will be involved.

Behavioral Intention

According to the need theory the BI should also contain the need or motivation. Therefore the ATB and PBC are multiplied with the corresponding motivation as given in (3.6). Putting (3.22) and (3.6) together, the BI component will be given by:

$$BI_t(\alpha) = MOT_t \times (ATB_t(\alpha) + PBC_t(\alpha))^T. \tag{3.28}$$

Note that the motivation here is not depending on the action being performed. Furthermore, on the right side the multiplication is between two vectors which results in the BI being one value. Hence, the information about why an agent wants to perform a particular action gets lost. In figure 3.2 for instance three agents representing children are displayed that all want to play football. All three agents might have a BI value of 1. However, the computation that led to this value is based on different motives, needs, and experiences.

Now that the whole model is discussed the next chapter will show how this model can be used for the simulation of the playground.

Chapter 4

The Playground

In this chapter the implementation of the model as in chapter 3 into the playground simulation is explained. In the playground the agents can choose to play different games, that meet the different needs of the agents. In comparison with the case study in [13] where also a computational playground is studied, here the emphasize is on the children (agents) deciding what to play in order to keep themselves happy rather than striving for a social status.

The first section describes what games can be played and how concepts like difficulty and interaction are integrated in order to implement the need-driven agents. The second section shortly describes the practical aspects of the agents used in the simulation. Finally, in the last section some details about the deliberation loop of the agents are given.

4.1 The Simulation of the Games

In the playground four different activities can be played: Football, rope skipping, chatting and rough & tumble. The latter has been proved to be an important activity played by children [40, 41]. Rope skipping is a game that can be played individually. On the other hand, football, chatting and rough & tumble are the social activities where at least on other agent is needed in order to play the. Each activity has a difficulty level between 0 and 1. How this difficulty is computed, depends on the type of the game, which can be the trick as in rope-skipping, or the other team in football.

In the rest of this section the computational playground will be explained in more detail.

4.1.1 Football

Football is a common game to play among children, because among other things it meets the three types of needs. Also in the computational playground this game is as such. First of all, it is a social game, with two teams playing against each other. Therefore, agents high on affiliation can increase their well-being by playing in a team with other agents that like him. Secondly, there is a clear competitive

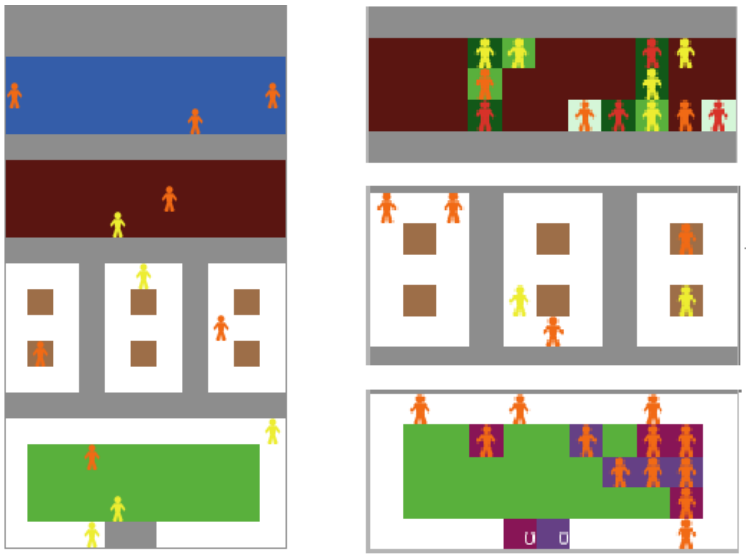


FIGURE 4.1: *The playground. The agents in the playground have different colors, which represent their highest motive, with orange for achievement, red for power, and yellow for affiliation. Left: The four different game areas with from the top rough & tumble, chat, rope skipping and football. Right top: Agents chatting, with the different colors showing different chat groups. Right center: Agents rope skipping. Right bottom: Agents playing football, with the different colors representing the two different teams. On the bottom the score is showed. The colors of the score correspond to the colors of the teams.*

aspect in the sense of winning. Not only will one team loose and the other win, the difference in score for both teams makes that a victory of 6-0 will be experienced as more successful than winning with 2-1. Also for agent high on power football is attractive, because he can learn from his team mates.

Modeling Football

Football will be played in two teams. The teams should contain a least 2 and at most 4 agents. If the size of the group with agents that want to play football is 8 or less, all agents will be randomly divided into 2 teams. In case of an odd number of players, one team will have one extra player. If there are more than 8 agents to play football, 8 agents are randomly chosen for the game.

The match can last for 1, 2 or 3 time steps, which is chosen randomly. During the match, new agents can arrive to the game, but have to wait on the side. Only when the current match is ended a new match can start where the new agents can participate in. The teams are displayed by two different colors on the patches.

4.1.2 Rope Skipping

Rope skipping is the only individual activity in the playground. In this task the agents choose a trick they want to practice. Each trick has another difficulty level: the higher the difficulty, the less likely the agent can perform the trick successfully. For the achievement agents it is all about this success to achieve. If they perform well, the outcome on competence is 1, 0 otherwise. For the power motive it is

about the learning. The more challenging the trick, the more the agents can learn. For affiliation agents there is no direct interaction in the rope skipping task. However, the feedback still has an influence on them.

Modeling Rope Skipping

The agents can choose between three different tricks with different difficulties. Their difficulties are 0.5 (easy), 0.75 (moderate) and 1 (hard). On the playground only six skip ropes will be available. If an agent wants to play with the skip rope and all of them are taken by other agents, he has to wait on the side. While waiting, at every time step he will decide if he still wants to do this activity or wants to change to another one, based on his BI. Each skip rope activity will take 1 time step.

4.1.3 Chat and Rough & Tumble

Both chat and rough & tumble are interactive activities. For achievement the challenge while chatting can be interpreted as making the others laugh or getting to know another child. Although rough & tumble is not about winning and finding out who is the strongest, for the achievers success can still be seen as played with that particular child or played with a group of three children. Note that in all cases the agents do not set this particular goals. For power it is the same as in the other two activities. They can improve their skills while talking or playing with others. The higher the skill of the partner, the more there can be learned. Finally, for affiliation, the drive is to play or talk with others and having a positive interaction. In both activities a group of agents can play together, but for the affiliate that does not mean that the result of the activity on acceptance can get higher. For instance, when one person is talking with only one other person the conversation is intense in the sense that both have full attention for each other. In the case of a group, the same attention needs to be divided and only a fraction of time and energy is spend with each person of a group. Therefore bigger groups do not automatically mean more acceptance.

Modeling Chat and Rough & Tumble

Chat and rough & tumble are computational speaking the same. However, agents can have a preference for one or the other, since the skill for one of the games is higher than the other. All agents that want to do one of these two activities, can ask one other agent to interact or play with. One by one they will look for a partner, who can accept or reject this request. Multiple chat or rough & tumble groups will appear, in which all agents talk or play with all others in his group. For example, agent i can choose to talk or play with agent j. In this case he can ask agent j to talk or play with. The exact process of choosing an agent to talk or play with, will be explained later on in this chapter. When agent j gets this request, he can choose to accept this request or reject it. This accept/rejection is based on his own BI of chatting or playing rough & tumble with agent i. If this BI is greater than or equal to 0 he will accept the request, and reject otherwise. If agent j accepts, agent i and j will belong to the same group

within the activity. When agent j already found a partner, this agent will also belong to the group. If now agent i or agent j gets another request and this one is also accepted, the group is extended with another agent. Note that the acceptance or rejection is only done by the agent that receives the request. This means that agents in the same group do not necessarily all have a positive BI towards each other. Each group exists out of a minimum of two agents and a maximum of all agents that want to chat or play rough & tumble. Every group is displayed by different colors displayed on the patches. Every conversation or play will take 1 time step.

In the case of a rejection, i.e. agent i wants to talk to agent j but agent j rejects this, agent i will handle this as an performed action. After all, his well-being decreases by being rejected and not performing this time step, caused by agent j. This information is stored in the memory, so that in the future agent i knows that wanting to talk with agent j does not result in an increase of well-being.

4.2 Agents as Playing Children

As in the proposed model, the agents have motive values and three well-being attributes that correspond to each of the motives. The values of the motives are one of the parameters that will be tested, so will depend on the type of experiment. Furthermore, the agents have a skill attribute for each of the four activities that can be played, a friendship value towards all other agents, and a memory to store previous experiences and context. These three concepts will be explained a little bit more in detail, since they are adjusted to this specific case study.

4.2.1 Skills

All agent will have a skill value for all four activities. Those are given, for agent i at time t, by $s_t^i(\alpha)$, with α= 'foot', 'chat', 'r&t' or 'rope'.

4.2.2 Friendships

From the start, the friendship values are always non-zero. Although the agents are still not familiar to each other, the friendship values already have an impact from the start. Not only is the action choosing influenced by it, also the given feedback for acceptance is equal to this value.

4.2.3 Memory

As said before, the agents need a memory to keep track of previous experiences. Because only the most recent experiences are relevant, only the last n experiences should be stored. However, this will take a lot of memory. Therefore, instead of storing the last memories, a decay value γ is used. This means

that, for example, the past experiences for the outcome on football is stored as:

$$\mathrm{OUT}^i_{past}(\text{foot}) = \sum_{k \leq n} \gamma^k \times \mathrm{OUT}^i_{t_k}(\text{foot}), \tag{4.1}$$

with n the total number of times agent i played football, and $\mathrm{OUT}^i_{t_k}$ of that match at time t_k.

4.3 Deliberation Loop in the Playground

Some aspects of the model were kept abstract, since they depend on the type of simulation for which the model is used. In the playground they are implemented as follows.

4.3.1 Action Selection

For each possible action the agents will compute the BI. The possible actions are the three levels in rope skipping, chatting with one of the other agents, playing rough & tumble with one of the other agents, or playing football. For the latter the BI for playing with each agent individually is computed. Since too many combinations of teams exist, the fact that a team can consist out of 4 players and who can be in the opposite team is not taken into account. The teams are made up randomly and therefore the agent cannot make a proper prediction of the outcome.

Then the agents will pick for each of the activities the highest BI value. The next performed activity will be the activity with the highest of the four BI values. When this maximum value is negative, which means a negative attitude towards every activity, the agent's task will become 'nothing'. He will be placed on one of the activities randomly, without performing anything.

4.3.2 Performance

The effort e^i_t of agent i performing action α is simply computed by $s^i_t(\alpha) * E^i_t$, i.e. the skill times the energy put in by the agent at time t. Football is a special case, because it both can last for more than 1 time step and the outcome of the game is based on the effort of the team, and not just one agent. For all agents in the team the total effort e^i_{total} of agent i is a cumulative value, i.e.

$$e^i_{total}(foot) = \sum_{1 \leq t \leq t_{match}} s^i(foot) \times E^i_t,$$

with t_{match} the total match time in time steps and E^i_t the energy of agent i on the i^{th} time step of the match. The total effort of the team is the sum of all effort of the agents of that team, i.e.

$$e_{team_k} = \sum_{i \in team_k} e^i_{total}(foot).$$

Difficulty

For all activities the actual difficulty needs to be computed and not from the point of view of an agent, like with the BI. The difficulty of rope skipping is straight forward, namely 0.5, 0.75 and 1 for the easy, moderate and hard trick respectively. For the other three activities the difficulty is based on the effort of the other agents. In case of football, the difficulty that team 1 has to cope with is the total effort of team 2 and the other way around, so $\text{DIFF}_{team_k} = e_{team_k}$, with $k \in \{1, 2\}$. The difficulty in case of chatting and rough & tumble is computed in a similar way, but instead of taking the total effort of the whole group, the average is taken.

Result of Performance

With both the effort of the agent and the difficulty of the task the formulas to compute the result of the performance as in (3.12) can be used. To compute the result of performing rope skipping, chat and rough & tumble (3.12) is used.

For football, a slightly different formula is used. In this way a difference can be made between winning with 1-0 and with 6-0. To compute the score of the match, both the result of team 1 as the result of team 2 is computed. Now the score of team i with team j the opposite team is computed by:

$$score_t^i = \mathcal{N}(2 + 10 \times \frac{\text{PERF}_t^i - \text{PERF}_t^i}{\text{PERF}_t^i(\alpha) + \text{PERF}_t^j(\alpha)}, 1). \tag{4.2}$$

By subtracting the performance of the opposite team from one's own team, μ will increase if one's own team is stronger, and decrease if the opposite team is stronger. Because it is normal distribution, it can still happen that the team with the lowest performance can win. In order to get only positive scores for both teams, the minimal score is set to 0. Also, with this distribution the score can be a non-integer so the score will be rounded to the closest integer.

4.3.3 Outcome

For the outcome on competence the results of the performance is needed. Because rope skipping, chat and rough&tumble have a binary result, the outcome is simply 0 or 1. For football this is different. The outcome then will be the score of the agent's own team minus the score of the opposite team. For all games the control will be the same, as in (3.13). Finally, to compute the outcome on acceptance the agents that participated in the activity are used. This means for chat and rough & tumble the group one performed the activity with and for football the agents of one's own team.

4.3.4 Feedback

The feedback is given by the agents that are doing the same activity. So, for example, all agents that are chatting, will give feedback to each other.

4.3.5 Storing of Outcome and Evaluation

To store the outcome the context is needed, as mentioned in section 3.2. Rope skipping does not need any context for the outcome itself. For chat and rough & tumble the context, which are the groups, determine the outcome, i.e. the difficulty of the activity depend on the group. However, it will take up to much memory to store the outcome for every specific group. Therefore, the group will be seen as one, and the same outcome will be related to every agent in the group. The same holds for football. Also here the outcome will only be related to each individual of the team, but not to specific team configuration, because of the complexity. The opposite team won't be used in the context.

As with the outcome the evaluation, without the feedback component, is stored. It is also linked to the context in the same manner as with the outcome.

After one agent received feedback from the rest of the group, the feedback is stored. Agent i, who received the feedback, relates the feedback given by agent j to activity α. Own performance will not be taken into account here.

Chapter 5

Experiments

In order to find an answer to the main question, i.e. what lies in the core of the emergence of the glass ceiling, it is needed to know why certain compositions of agents form groups and by what factors this is influenced. Therefore the influence of feedback, skills and friendship on different types of need-driven agents will be tested. This will all be done in a closed environment. In other words, the agents can not choose what activity they want to play. In this way the focus is not on the emergence of seperate groups of agents, but rather on what kind of factors, both nature and nuture, stimulate agents to interact with each other. The first three hypotheses cover this. Then the findings of these experiments will contribute to an explanation of why a seperation of the agents might or might not appear, which is studied in the fourth and final experiment.

5.1 Hypothesis 1: Feedback changes behavior, depending on the motives of both the feedback giver and receiver.

The feedback that agents give to each other is an important social aspect in the model. The type of feedback depends on the motives and it is influenced by the motives of the agents in two ways. First of all, the feedback is weighted by the motive values of the agent that gives this feedback. Secondly, the affiliation motive of the agent that receives the feedback determines in the extent to which the well-being on acceptance is influenced by that feedback.

In the context of a group feedback is relevant. If an agent is affected by this feedback, i.e. his well-being gained more or less than without getting feedback, it can be assumed that later on the agent will adapt his behavior in order to satisfy his needs as much as possible. This can be done in two ways. He can change his goal choice such that it is more in line with the direction of the group or he chooses a different group where his preferred goal choice is more appreciated.

Env		Motives of target agent	
#Agents	1	Mixed	No
Games	Rope Skipping	Achie	U(0,.25) + 0.6
Friends	0	Power	U(0,.25) + 0.6
Feedback	No	Runs	30

TABLE 5.1: *Set-up for scenarios without feedback*

Env		Motives of target agent		Motives of surrounding agents	
#Agents	6	Mixed	No	Mixed	No
Games	Rope Skipping	Achie	U(0,.25) + 0.6	Achie	U(0,.25) + 0.6
Friends	U(0,0.4) - 0.2	Power	U(0,.25) + 0.6	Power	U(0,.25) + 0.6
Feedback	Yes	Affil	0.7	Affil	U(0,.25) + 0.6
Runs	7-10				

TABLE 5.2: *Set-up for scenario with feedback*

5.1.1 Method

In order to find the influence of the group on the goal choice of the agents the rope skipping activity will be studied. This activity has three levels of difficulty, i.e. easy, moderate and hard, which can easily be distinguished in the results. In the first scenario single motive agents will be used. They only have the power, achievement or affiliation motive. In this part no feedback will be given. This scenario represents the case of an individual choosing his own goals, without interference of others. Each scenario will be run 30 times. Afterwards, for each agent three values will be computed, namely the proportion of times that one of the three difficulties is chosen. Then, for each agent the most chosen level will be plotted as a disc, with the color representing the level and the radius representing the proportion, i.e. the bigger the disc, the more the agent choose this goal, relatively speaking.

Then, to study the influence of the group, 6 agents are placed in the rope skipping zone. One of the agents will be the so-called target agent, i.e. the agent of which the group influence will be tested. The five other agents represent the group, that judge the target agent on his performance, i.e. give feedback to him. The target agent therefore needs to have an affiliate value, such that the feedback will influence his well-being and therefore also his goal choice. The affiliate value will be set to 0.7 for all target agents. In order to let the friendship value not interfere because of the affiliate motive, in the case of achievement or power feedback the friendship values are set to 0. For affiliation feedback the friendships are non-zero, because this is the core of their feedback. The result of the chosen goals will be analyzed in the same as in the non-feedback case. The scenarios will be distinguished by the motive of the target agent and the common motive of the surrounding agents. Therefore 9 different scenarios will be set up: A group of achievement feedback, power feedback or affiliate feedback, for target agents with the achievement, power or affiliate motive.

5.1.2 Results

Goal choice of agents with a achievement, power or affiliation motive without feedback

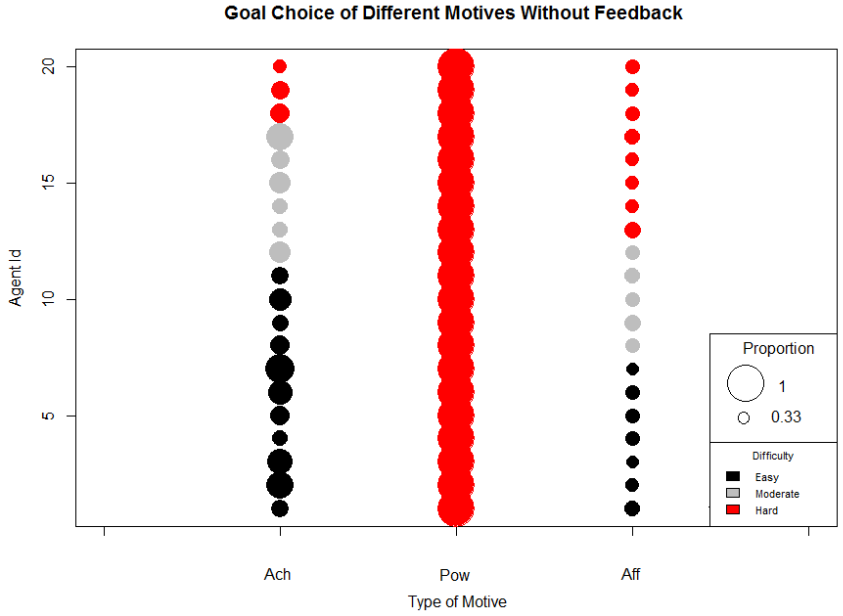


FIGURE 5.1: *Goal choice of agents with a achievemen, power or affiliation motive without feedback.*

The three different motives choose goals with difficulty in different ways. Looking at the colors representing the difficulties, both achievement and affiliation do not have a preference related to their motive, although achievement tends to avoid the more risky level. The agents driven by power only choose the hardest task, because in that case their skill can increase the most. Another difference that can be obtained is the proportion of the most chosen goals. The size of the disks of the power agents is the biggest, which stand for all the time the same task, namely the hardest one. Looking at the achievement agents, the size of the disks differ, which indicates a more random goal choice. This is because of the incentive of the achievement agents: it is about having success or not and this aspect has a random factor in the model. Some agents have luck at the hardest level and think this is an easy task. They might stay there for a while, until they discover that other tasks are easier. Finally, the agents with the affiliation motive show similar results as the agents high on achievement, i.e. no clear preference, but the cause of this is different. Again looking at the incentives, affiliate are looking for acceptance. However, rope skipping does not provide this, unless feedback is given. The agents high on affiliation do not gain anything on well-being so they keep choosing random difficulties. Therefore the small size of the disks, since the difficulty that is chosen the most is around one third of the total.

Goal choice of agents high on achievement with three types of feedback

The goal choice of agents with the achievement motive is shown in figure 5.2. The disks on the most left side are again the results of the scenario without feedback, as in figure 5.1. This in order to compare

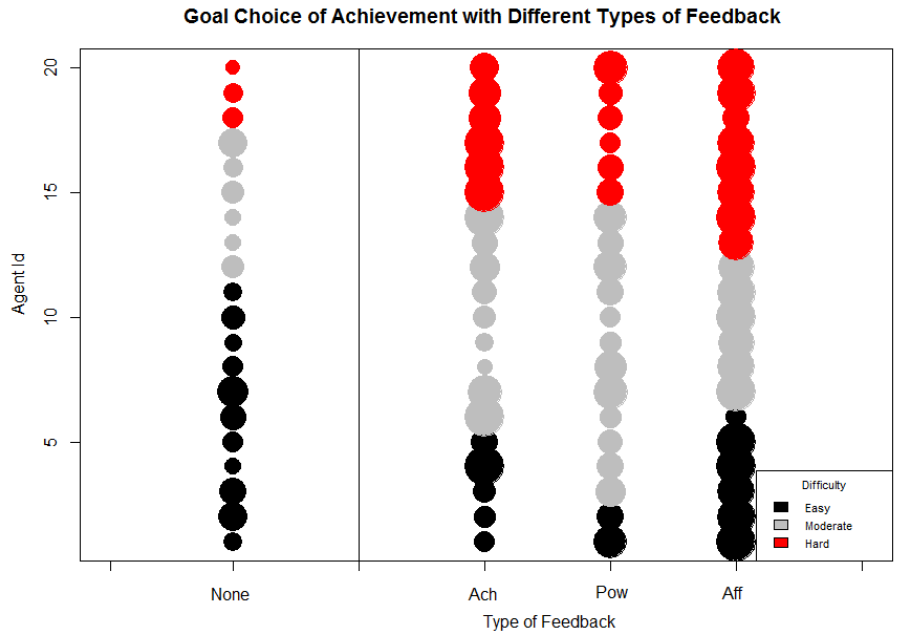


FIGURE 5.2: *Agents driven by achievement with different types of feedback.*

the results with the scenarios with feedback. It is clear that, with the given feedback, achievement agents tend to choose relatively higher difficulties, no matter the type of feedback. This corresponds with the findings from [14], that achievement agents need feedback in order to know how well they are doing. They now dare to take more risk. When the agents get only achievement feedback, the results correspond to those of the risk-taking model [26], where is argued that people high on achievement mostly choose actions with a moderate risk. This result can be explained by the characteristics of the achievement feedback. The feedback is negative in case of failure, and positive in case of success. Therefore, the lower the difficulty, the more an agent benefits from the feedback. On the other hand, if an agent has success, it is compared with the difficulty itself. If this difficulty is low, the feedback is low too. This can be interpret as succeeding in a easy task is not as impressive as succeeding in a hard task. In combination with probability of having success, i.e. the easier the task, the more success and the harder the task, the less success, this results in the fact that agents high on achievement benefit the most from the moderate risk tasks.

With power feedback, the agents gain more well-being in another way. The harder the task, the higher their skill value will get. Since the feedback from power agents depend on that value, the higher the skill the higher the feedback. Therefore, the achievement agents benefit more by taking more risk. This does not result in the agents only choosing the hard level, because they still care about having success.

Finally, the affiliation feedback gives another pattern. The ratio of most preferred goals is almost random, i.e. all one third. This is because from the first step the agents explore and choose a level arbitrary. If they then receive positive feedback from the surrounding driven by affiliation, they keep at that level. The affiliate feedback, i.e. the friendship, stays fixed, so they keep getting positive feedback, regardless of their success. This also explains the high radius of the disks, since they stay at the same task for almost all the time and do not switch to other difficulties.

Goal choice of agents high on power with three types of feedback

In figure 5.3 the results of the agents high on power can be seen. Again on the most left the case without feedback is plotted, in order to compare to the cases with feedback. Overall it can be concluded that the agents keep the preference for the hardest level possible. The three types of feedback have different

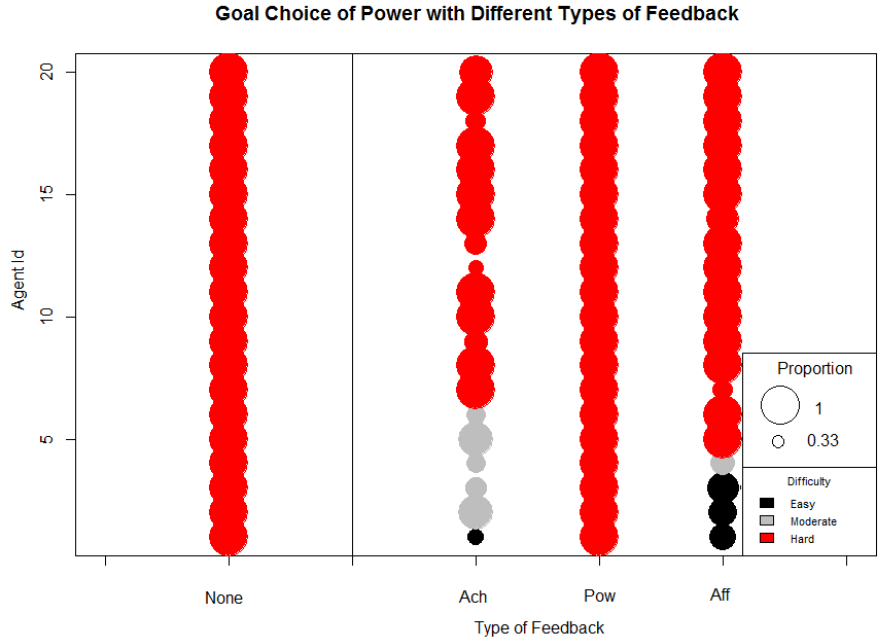


FIGURE 5.3: *Goal choice of agents driven by power with different types of feedback.*

influences on the goal choice of agents high on power. First of all, it looks like the feedback of other power agents do not have any influence in comparison with no feedback at all. This is because the feedback on power is indirectly related to the difficulty of the task itself, namely the skill value. The higher the difficulty, the more the skill can be improved. Therefore, practicing the highest difficulty results in the best feedback.

With achievement feedback, the agents respond to the actions of the power agent by looking at his performance. Since the power agents choose the hardest difficulty, the probability of having success in the beginning is very low. The feedback from the achievement agents, therefore, will be negative. This makes that the power agent relates the hardest task to negative feedback and might change his preference. The disks that are gray or black, representing a majority of the moderate or easy task chosen, are not that big. That means that the feedback does not make a power agent fully choose another task. Also the fact that not all red disks are as big as in the non-feedback situation shows that the agent choose other levels besides the hardest difficulty.

On the right the results are shown of the goal choice when affiliation feedback is given. The feedback value is equal to the friendship, i.e. when the affiliate agent gives feedback to the power agent, he looks at his friendship quality towards the power agent. This feedback is, like the achievement feedback, again independent of the difficulty of the task. When the power agent is liked by the affiliate agents,

it does not matter what he chooses, his feedback will always be positive. Therefore, the red disks in the graph. The few non-red discs represent the scenarios where a power agent was not liked by the surrounding. First he tries the hard task, but gets negative feedback. Accordingly, he tries the other two tasks, but again he gets negative feedback. The black and gray results show how the power agent was trying to find a task where he would receive better feedback.

Goal choice of agents high on affiliation with three types of feedback

Finally, the results of the agents high on affiliation getting feedback, again with the no-feedback case, is shown in figure 5.4. Comparing to the case of no feedback, also here the feedback clearly has an

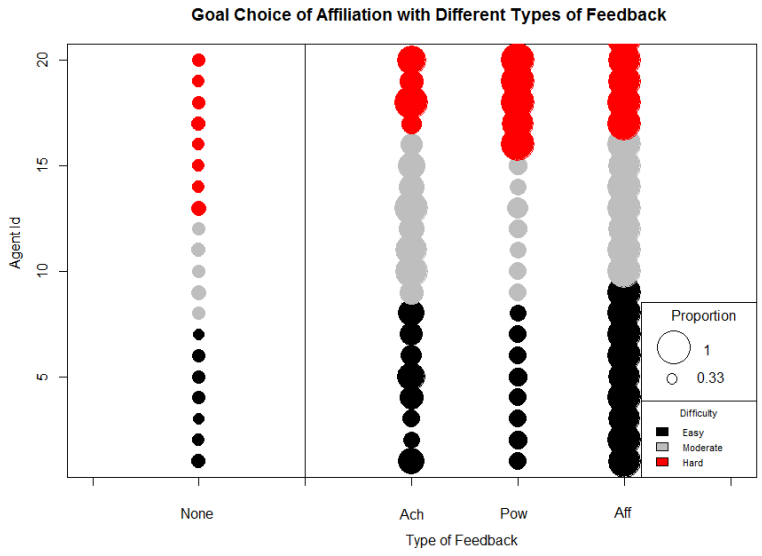


FIGURE 5.4: *Goal choice of agents high on affiliation with different types of feedback.*

influence on goal choice. Also similar influences from the type of feedback can be obtained as with the previous results. Achievement stimulates dynamic behavior, which can be concluded by the different sizes of the disks. In the case of a power driven environment, if the affiliate agent chooses to do the hardest level in most of the time, it will choose that one in almost 100% of the time. That is because the affiliate get the most positive feedback, since his rope skipping skills will improve the fastest. With affiliate feedback the agents tend to choose the less risky levels. They will stay there, i.e. the disks are that wide, because the feedback stays the same and once they get an increase in well-being, they have no need to change levels.

5.1.3 Conclusion

In general it can be concluded that each type of feedback has a different type of influence on behavior, depending on the motives of the feedback receiver. Achievement feedback stimulates more dynamic

behavior, whereas affiliation stimulates one favorite action. On the other hand, the behavior of achievers becomes more risk taking when getting feedback, independent of the type of feedback. This corresponds to the findings in [14]. Furthermore, the power agents take more risk, which is supported by the findings in [14, 26, 31]. Finally, affiliate agents tend to choose less risky behavior, which is also found in [31].

It is obvious that feedback, in particular in combination with agents driven by different needs, plays a role when it comes down to goal choice. Even more important, acting as a group, agents are able to influence each others' behavior with this type of interaction.

This supports the idea of social interaction affecting the emergence of different social groups. If certain motives are more presented in groups the feedback will also be directed by that motive. A new member can, depending on his own motives, choose to join the group because he notices that his needs are met. On the other hand, he can also choose to find another group where the behavior is more in line with his preferred direction. Therefore different groups can emerge.

5.2 Hypothesis 2: Stability of a group depends on the motives that are highly presented within the group.

The main objective here is to see how different motives influence group interaction and which motives stimulate playing together. Note that the agents still play for their own sake and are not trying to achieve a group goal. In other words, they do not have to form a group and cooperate together.

Although the agents are free to choose what action they want to do, they can be forced to perform in a group. For instance with chatting, agent A chooses to talk to agent B. Then agent C starts talking with agent B too, so agent A has to interact with agent C. If the outcome turns out to be negative for agent A, he will link this experience to both agents. In the future agent A might not want to play with agent B anymore, because of the risk of agent C joining again. On the long run this can result in a stable group of agents playing together that actually really like playing together, with only positive outcomes. The question that can be asked how the motives influence this stability.

5.2.1 Method

For this hypothesis only the chat activity will be used. In this activity the agents can form groups within the activity, as is mentioned in section 4.1.3. In all runs the agents have a non-zero value for the three motives. First, only one type of agents are used, i.e. agents that are highest on the same motive. After that, populations with two types of agents are tested, to see which type of motives in agents form a stable group. The combinations are achievement with power (ach-pow), achievement with affiliation (ach-aff) and power with affiliation (pow-aff).

Since also smaller groups can exist within the chatting activity (see section 4.1.3), the average group size of agents that are chatting at every time step is counted. Also only the agents that participate in the chat activity are considered. This is because if an agent thinks none of the other agents can serve

as a proper chat partner to increase his well-being, he won't be chatting at all. In this case it also important to mention the number of active agents, since an average group size of three agents does not say anything about how many agents are actually chatting.

Env		Motives of the agent	
#Agents	12	Mixed	Yes
Games	Chat	Achie	U(0,.25) + 0.2 $\times\phi$
Friends	U(0,0.4) - 0.2	Power	U(0,.25) + 0.2 $\times\phi$
Feedback	Yes	Affil	U(0,.25) + 0.2 $\times\phi$
Runs	7-10		

TABLE 5.3: *Set-up for hypothesis 2*

5.2.2 Results

Populations with agents having the same motives

In figure 5.5 the results of the populations with agents having the same motives is shown. On the x-axis the time is plotted,on the y-axis the average size of the groups. The average number of active agents is represented by the size of the dots. A clear difference between the different types of populations can be obtained.

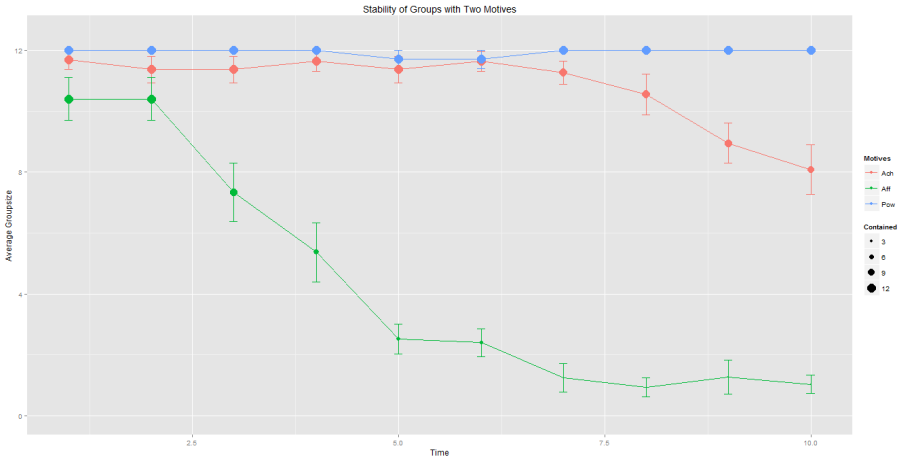


FIGURE 5.5: *Stability of groups over time of agents mostly driven by the same motive.*

The size of the groups with mostly power-driven agents has a value of 12, which means that all agents where contained in only 1 group, i.e. they all played together the whole time. This is because all agents choose the agent with the highest skill to talk with, which is the same agent for everyone. The feedback that they give to each other is for all close to zero, because they start with the same skill and there is not much skill difference. Therefore acting in a group does not dissatisfy any of them and the group stays stable.

When mostly driven by achievement, the agents started to play together but after a short period of time the group size decreased. In the beginning the same cause of group formation as with the power

agents can be found. The agents choose that agent where they think they can have success, which is again the same agent. However, not all agents are guaranteed of having success, because of the random factor. Therefore once an agent fails he gets negative feedback and he will blame all agents of the group for that. In the next time step he does not want to play with any of the agents anymore.

Finally, the population with all the agents being driven mostly by the affiliate motive is the most unstable one. After only ten time steps almost every agent stops interacting with the others. Since friendship values are important for affiliate agents, this might have an effect on the average group size. To study the influence of the friendship these values at the beginning of the simulation are varied. The results are shown in figure 5.6. The friendship values started with values in $[0, 0.4] - \alpha, \alpha \in \{0, 0.1, ..., 0.4\}$. In the graph it becomes clear that the more negative the friendship is towards each other, the less agents participate in a group. In the case of all negative values, not even one group emerged. This is because the well-being of all agents only decreases after one interaction. Therefore it is better for the agents to don't interact at all. At the same time when all agents have positive attitudes to each other, it does not guarantee that one stable group emerges. This is caused by the fact that the friendship values towards each other are not symmetrical. Agent A can have a positive value towards agent B of 0.4, while the value of the friendship the other way around equals 0.05. Agent A might have high expectations of interacting with agent B, but is disappointed. He experiences this as a rejection and does not want to interact anymore with agent B.

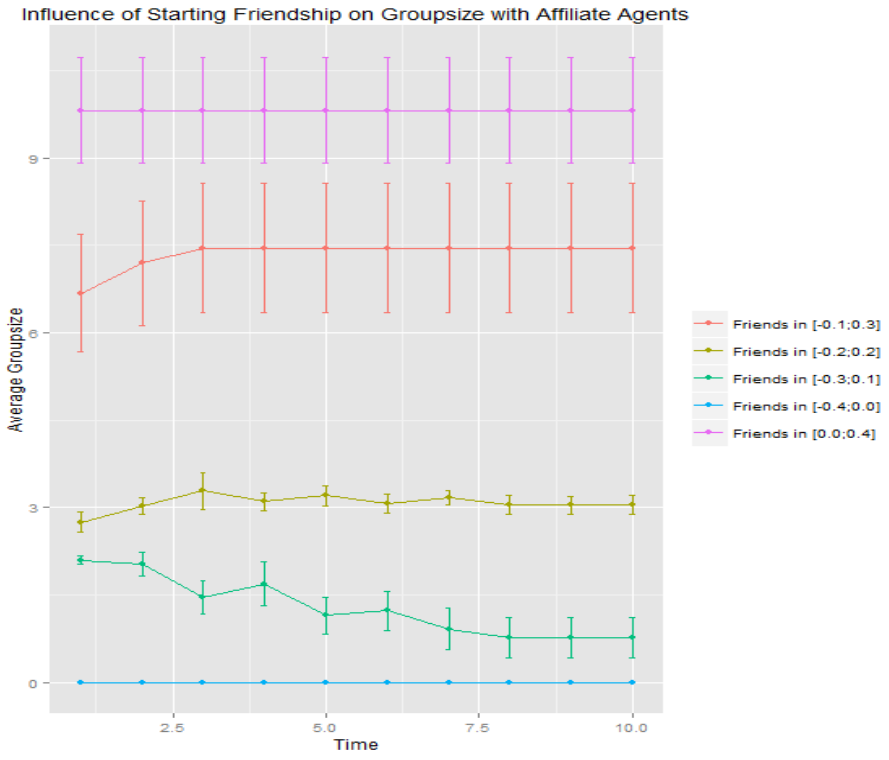
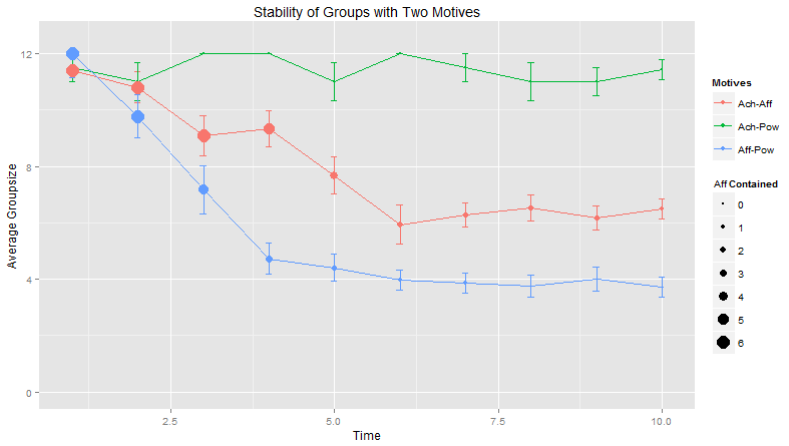


FIGURE 5.6: *Group stability over time of affiliate driven agents, starting with different friendship values.*



Mixed populations

The results of the population existing out of two different types of agents is plotted. The three lines represent the ach-pow group (green), the pow-aff group (red), and the ach-aff group (blue). The achievement agents together with the power agents are a stable interacting group. From the previous hypothesis it became clear that achievement agents choose higher risk goals when getting power feedback. Together with the power agents the chat skill will develop faster and therefore having success on more difficult goals is more likely. Both power and achievement agents benefit from this situation.

In the two other cases, no such merge of two groups driven by different motives can be found. In both cases the number of agents that are still contained in the group is around 6. This still gives no insight in if the agents mix or that agents with the same motive drop out and the others keep interacting. Since from the previous results it became clear that affiliate tend to drop out of interaction, in the same plot the number of affiliate agents contained in the group is plotted. The blue dots correspond to the blue line, i.e. pow-aff, and the green dots to the green line, i.e. ach-aff. In the latter case almost all affiliate drop out and most of the achievement agents stay together, like in the previous results. Almost the same holds for the affiliate with power population, although some affiliate agents might stay in the group. The reason for this difference can be found in the feedback. The feedback of achievement is much more dynamic, since it depends on the success. This success, being 0 or 1, changes all the time. Once an affiliate fails, it gets negative feedback. Affiliate are the most sensitive for feedback and will drop out immediately after this negative feedback. With power feedback this is different, because there is no big skill difference. Therefore the feedback will be close to zero and has less effect.

5.2.3 Conclusion

Looking at only populations that are highest on one motive, it looks like both the power and achievement driven agent population form (almost) stable groups. On the contrary, the existence of an interactive group of affiliate agents depend on the mutual friendship that the agents have towards each other. Also with the presence of other motives, the affiliate agents drop out very soon, which leaves a stable group of agents with a non-affiliate motive.

Linking these findings to the glass ceiling problem it can be concluded that if indeed the needs of need-driven behavior differ for men and women, the affiliate motive seems to have the most influence on a separation in a population.

5.3 Hypothesis 3: While playing football, agents high on affiliation will have better mutual relationships with other agents if they have relatively higher football skills.

In this experiment affiliate agents having a better football skill than the other agents is tested, specifically how this has an effect on the relationship between the agents. Also the influence of feedback is studied, to see if the combination of a difference in nature, namely skills and motives, and social interaction, namely feedback, has an effect on mutual relations in particular. Results of this experiment can argue if differences in skills can affect an emergence of different groups, and what other type of social factors influence this effect.

5.3.1 Method

In order to test the hypothesis the friendship values of the agents will be studied. As explained in chapter 3.2.4 the friendship from agent i towards agent j is the sum over all well-being gained or lost while interacting with agent j. If the activities performed together turned out to be a failure all the time, the mutual relationship will be negative. On the other hand, if the performance together turns out to be successful, this will result in a mutual positive relation. To evaluate if an activity has been performed successfully or not, depends on the interests of the agents. The friendship values of a population with N agents can be summarized in a $N \times N$ matrix with values a_{ij}, $a \in [-1, 1]$ and $i, j \in \{1, ..., N\}$. Instead of values colors will be used. Then, the value a_{ij} in the matrix represents the friendship of agent i towards agent j. This matrix can give a quick overview of the mutual happiness while playing together. To summarize multiple runs each scenario will be summarized in nine box plots: For each of the three motives, the agents are categorized according to that motive that they are most driven by. Then one box plot represents all friendships from the agents of one category towards all agents from also one category. For instance, one of the box plots represent the friendships from all agents high on achievement towards the agents high on affiliation.

Two different scenarios will be tested. The variables that are fixed during the different experiments and their corresponding values are given in table 5.4. In the football field 12 agents with mixed-motives are placed, each four agents are highest on one of the motives. The friendship after 50 time steps is used and agents receive feedback from each other. Then, in scenario A, first the friendships between the agents starting with the same skill values will be explored, see table 5.5. These results will be compared with the situation, scenario B, where agents high on affiliation start with higher skill values than the other agents, see table 5.6. Besides the friendship also the role of the feedback will be studied, since the influence of the received feedback depends on the affiliate motive. Agents high on affiliation are

more sensitive for this social interaction, and should therefore also be taken into consideration. Both scenario A and B will be repeated, but now without the agents giving feedback to each other. These are scenario C and scenario D respectively, see table 5.7 and 5.8.

Env		Motives	
#Agents	12	Mixed	Yes
Games	Football	Achie	U(0,.25) + $\phi\times$ 0.2
Friends	U(0,0.2)	Power	U(0,.25) + $\phi\times$ 0.2
Runs	7-10	Affil	U(0,.25) + $\phi\times$ 0.2

TABLE 5.4: *Set up for all runs of hypothesis 1.*

Env	
Foot Skill	U(0,0.2) + 0.1
Feedback	Yes

TABLE 5.5: *Set-up for football with feedback.*

Env	
Foot Skill	$\begin{cases} U(0,0.2)+0.5 & \text{if } \max_{\text{motive}} = \text{Affil} \\ U(0,0.2)+0.1 & \text{otherwise} \end{cases}$
Feedback	Yes

TABLE 5.6: *Set-up for football with feedback and affiliate having better football skills.*

5.3.2 Results

Agents playing football with the same skill

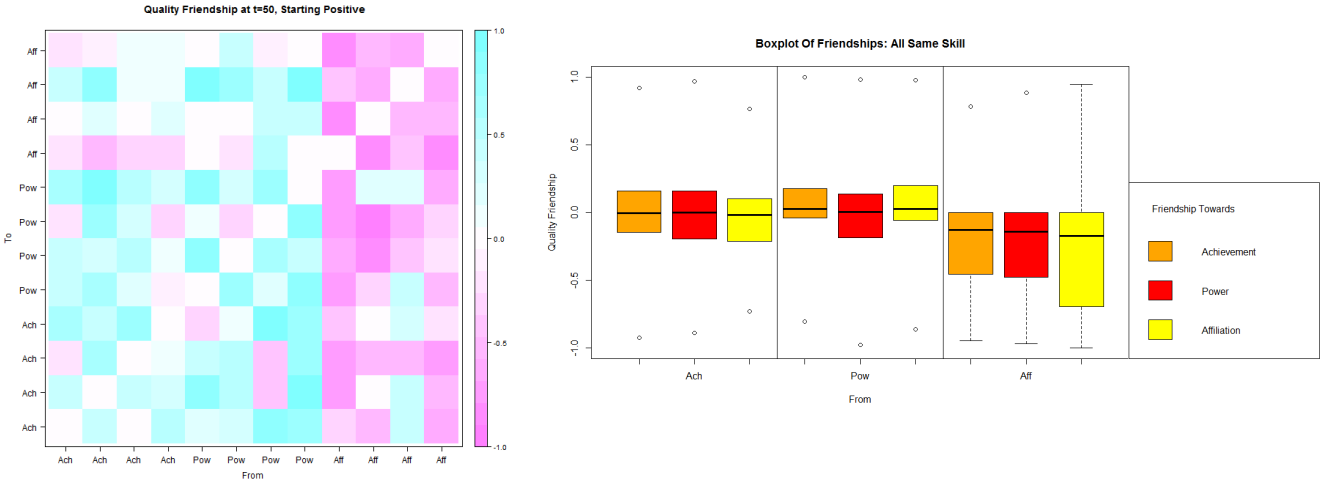


FIGURE 5.7: *Friendships at time $t = 50$ in situation H1A. Left: Friendships of the agents after one running. Right: Summary of friendships from agents high on one motive towards other agents high on one motive*

In all of the runs of scenario A, non of the populations have been fully happy with each other after 50 time steps. The friendships of one the runs is displayed in figure 5.7 (left). The matrix shows the friendship values that vary from -1 (pink) to +1 (blue). The colored square in column i and row j

represents the friendship value from agent i towards agent j. Note that the matrix is not symmetrical, which means that when an agent likes another agent, this attitude is not always mutual. The mostly pink squares on the right represent the friendships from the agents high on affiliation towards the others. They have a negative attitude towards all other agents, even towards other agents high on affiliation. All friendships started with a positive value between 0 and 0.2, which makes this situation remarkable. A positive attitude means that the agents give a positive feeling of acceptance towards each other, which would create a so-called snow ball effect. Nevertheless, the agents high on affiliation end up disliking each other.

In figure 5.7 (right) a summary of all the friendships of the runs is shown. All the friendships are divided in 9 different categories: The friendships from agents high on achievement, power, or affiliation (x-axis) towards other agents high on achievement (orange), power (red), or affiliation (yellow).

It can be easily seen that the attitude of the agents high on affiliation is much more negative towards the others than from the other agents. Already a difference can be obtained, without a skill difference. In other words, affected by different needs and social interaction like feedback make that one part of the population, here the affiliate agents, do not fit in the group. Even tough the agents can only play football here, one can assume that the affiliate agents would choose a different type of activity. This means that, at least in a setting as football, the effect of different motives makes that different groups might emerge.

Agents playing football with affiliate having higher football skills

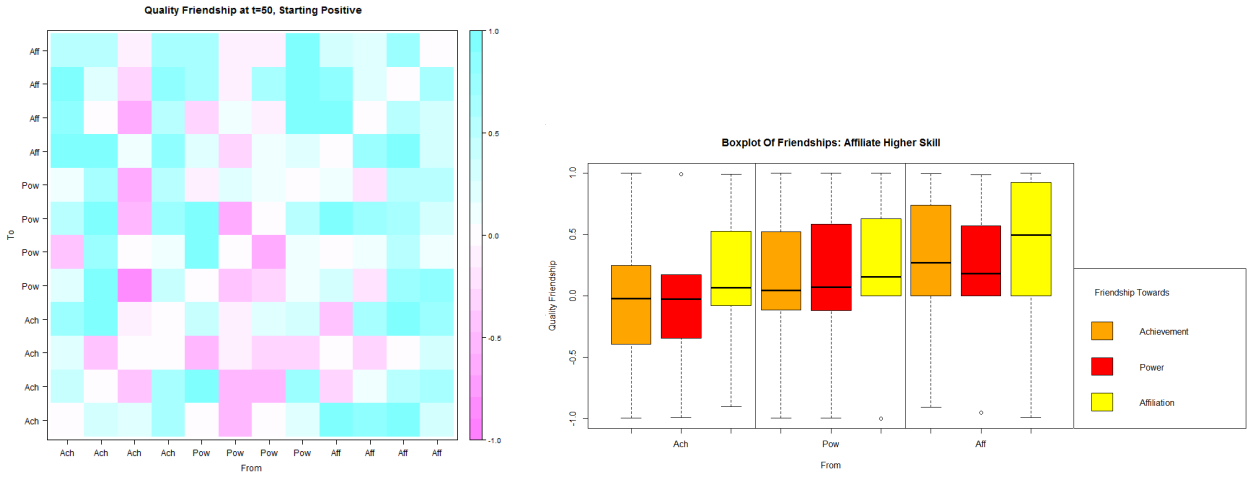


FIGURE 5.8: *Friendships at time $t = 50$. Left: Friendships of the agents after one run. Right: Summary of friendships from agents high on one motive towards other agents high on one motive.*

The question now is if the same pattern occurs when starting with set up B, i.e. starting with higher skill values for the agents high on affiliation. Again one of the friendship matrices after 50 time steps is plotted in figure 5.8 (left). It is easily obtained that in scenario B the friendship values reach more and higher positive values. Also the summary of all the runs after 50 time steps are shown in figure 5.8

(right). It is obvious that the agents high on affiliation like the others much more. Moreover, also the friendship values between achievement and power agents are more positive. Clearly, the higher skills of the affiliate agents has an influence on the whole group dynamics. This result can be explained by the role of the interaction. The feedback on competence and control depend on the skill values. The higher the value, the better the feedback. The affiliate agents are sensitive to that, so their well-being increases strongly. This will result in positive friendship towards the others. Also, both the feeling of acceptance as the feedback from the affiliate agents towards the others is again based on the friendship value, which was positive. This 'happiness' of the affiliate agents therefore makes that other agents gain more at least on affiliation, and this makes that the friendships get higher values. Although the feedback of power agents is more negative, since the affiliate agents are better skilled, the fact that the power agents can learn more compensates for that.

Agents playing football with and without affiliate having better skill, without feedback

Env	
Foot Skill	U(0,0.2) + 0.1
Feedback	No

TABLE 5.7: *Set-up for football without feedback.*

Env	
Foot Skill	$\begin{cases} U(0,0.2)+0.5 & \text{if } \max_{\text{motive}} = \text{Affil} \\ U(0,0.2)+0.1 & \text{otherwise} \end{cases}$
Feedback	No

TABLE 5.8: *Set-up for football without feedback with affiliate agents having better football skills.*

In these two scenarios the runs of scenario A and B were repeated, but now without the agents giving feedback towards each other. The results are shown in figure 5.9. Two main differences can be obtained. First of all, in both cases (agents high on affiliate with higher skill or not) all agents show more positive attitudes towards each other, compared to the same scenarios with feedback. Secondly, there is not much difference between affiliate having better football skills or not.

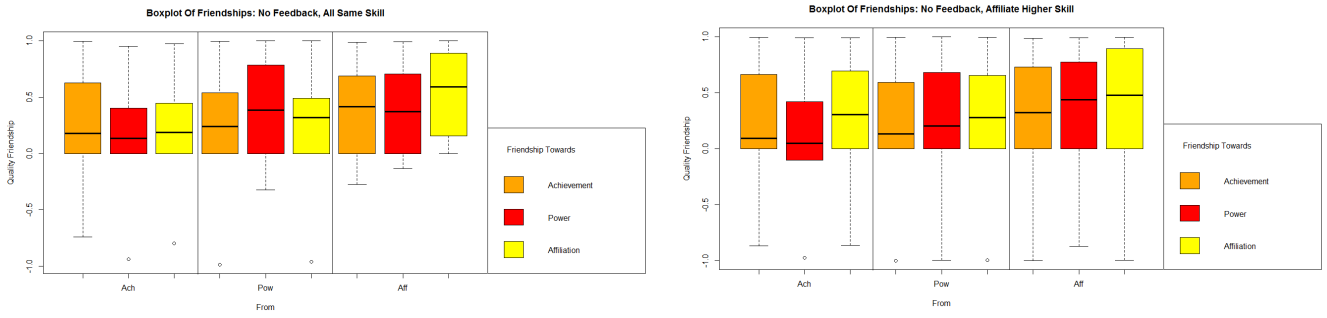


FIGURE 5.9: *Summaries of friendships at time $t = 50$ with no feedback. Left: All agents start with the same skill values. Right: Agents high on affiliation start with higher skill values than the others.*

5.3.3 Conclusion

Three conclusions can be drawn from the above results. First of all, a difference in interests make that affiliate are not happy while playing football. Seconldy, if those affiliate agents have better football skills than the others, their well-being increases and the friendships are mostly positive. Moreover, even the friendship between achievement and power agents is affected in a positive way. The third and final finding is that both the first and second effect are not found if the agents do not give feedback towards each other.

These results argue for an influence of self-organization when looking at group emergence. Both skill differences and a difference in motives, both nature influences, has no effect if social interaction is not taken into consideration. Only when the social interaction is included, namely the feedback, an effect of disliking towards each other is found, which might result in a split of the population. Futhermore, again the affiliation motive is most affected by the social interaction. This has influence on the emergence of different groups in that sense that affiliate without having the proper skills will not be stimulated to interact with non-affiliate. They will rather try to find other groups where they can satisfy their needs.

5.4 Hypothesis 4: The emergence of different social groups can not be explained just by differences in nature, or just by nurture influences, but by the self-organization, i.e. the combination of small differences between boys and girls, and social interaction.

Now that there is more insight on why agents interact with each other or might avoid each other, the emergence of an actual split in the agent population can be studied. In particular, which factors influence this split and if nature, nurture, or the combination of the two has the greatest impact.

5.4.1 Method

In every run 12 agents are placed on the playground. Then, the influence of four different factors on the emergence of different groups are tested: 1) Skills, 2) feedback, 3) friendship and 4) motives. In all cases, except for the feedback, the population of agents is split in half where one group gets different values then the other group. How these four factors are used in the experiment is explained in more detail below.

1. In hypothesis 3 it became clear that the skill values of the agents have an influence on the friendships and therefore on the choices of agents to play with. Two different scenarios with respect to the skills are tested. In the first scenario all agents have the same skill values, albeit with some variation. In the second scenario the population of agents will be split, where one group starts with higher skill values for chat and rope-skipping, and the other group starts with higher skills for rough and tumble and football.

No factors	One factor	Two factors	Three factors
Basic Scenario	Feedback Group favoured Skill difference	Feedback & group favoured Feedback & skill differences Group favoured & skill differences	Feedback, group favoured & skill differences
Tested on four different populations			
Ach-Pow	Ach-Aff	Pow-Aff	Mixed

TABLE 5.9: *All 32 different scenarios that are tested for hypothesis 4.*

2. In all three hypotheses it was concluded that feedback has an influence on both friendships, specially for agents high on affiliation, and on goal choice depending on difficulty. In some actions, like chatting or rough & tumble, other agents are goals and their difficulty for a perfomance depends on their skill and mutual relations. Therefore feedback also influences the choice of agents to play with. The two scenarios that can be tested considering feedback are simply agents playing with and without giving each other feedback on their actions.

3. In hypothesis 2 the importance of the starting value of the friendship has been shown. For agents high on affiliation this friendship is an important factor when choosing another agent to play with. In order to model this biased view on each other the friendship values are manipulated in a ingroup/outgroup way. The friendship values from an agent belonging to one group starts positive towards all other agents from the same group and negative towards the agents of the other group.

4. From all three hypotheses it becomes clear that the value of the motives have an influence on friendship, goal choice, and group stability. Again two different scenarios are tested, where in one case the agents all are highest on one of the motives arbitrary, independent of the group they belong to. In the other case one group will be highest on one motive, and the other group on another motive. The case where all agents are highest on the same motive is not tested.

Since also the combination of these factors are important for the study of self-organization, 32 different scenarios are tested, see table 5.9. If multiple factors are tested at the same time, the population is split in two groups and according to these groups the differences are applied. So for example, in the scenario where the influences of different skills and different motives are tested, all agents of group 1 are better in chat than group 2 and are all highest on achievement. Group 2 then is better in rough & tumble and is highest on affiliation.

Finally, a new measure is introduced in order to get an indication of how separated the two predefined groups are from each other. This measurement is called the split value and is computed as follows: At every time t, for every activity the absolute difference between the number of agents from group 1 and the number of agents of group 2 is calculated. The sum of these values is the split value of the playground at time t. If there is no separation, i.e. the agents interact with each other regardless their group, the split value will be close to 0. On the other hand, if agents only interact with agents from their own group, the split value will 12, since there are 12 agents on the playground.

The split values from time step 5 up and until 15 are computed and averaged. The extent of the emergence of different groups in one run can be expressed in one value between 0 and 12. Multiple runs of 1 scenario will be summarized in a box plot.

5.4.2 Results

First the influence of each of the factors on group split will be discussed. Later on this will be studied in more detail, to see which factors have an interaction effect, i.e. cause a self-organization effect.

Influence of one factor

In figure 5.10 the results of the runs are displayed, where a distinction is made between scenarios with and without feedback, favouring of own group members, common needs as a group, and having better skills respectively. In all four cases it can be conclude that the tendency to seperate as a population is higher when from the start two slightly different groups are placed in the playground or social interaction is included. There can be an effect obtained by both nurture factors (feedback and favouring of own group member) and nature factors (different motives and better skills), with the latter the most convincing influence.

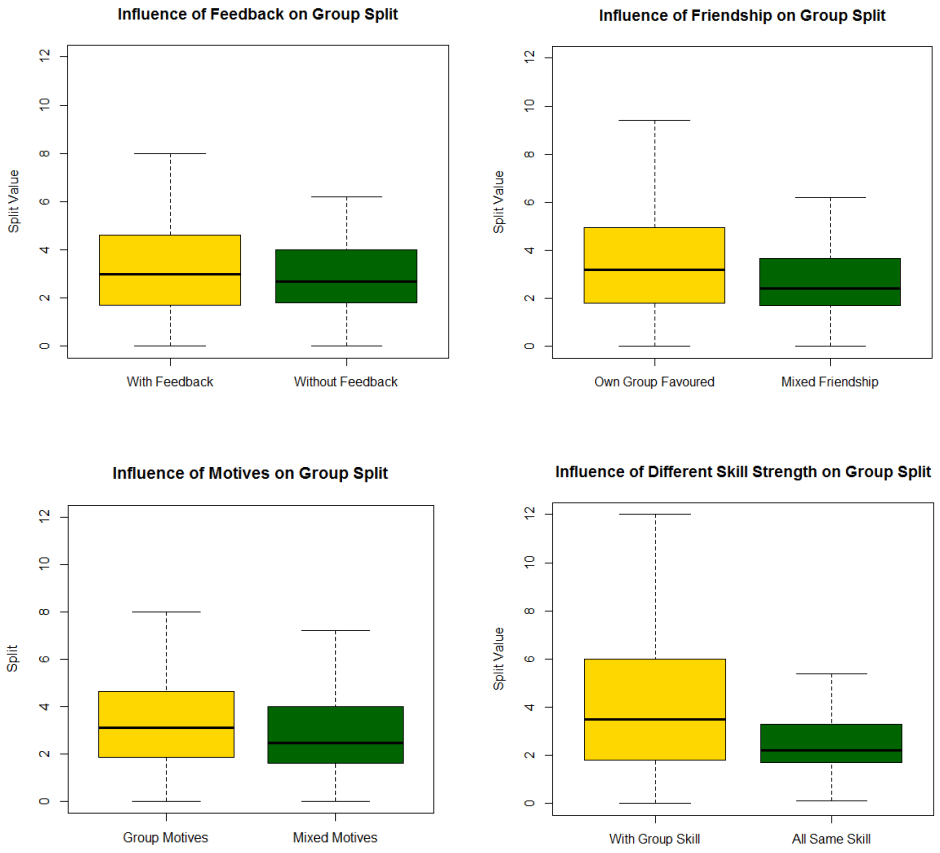


FIGURE 5.10: *Effect of each factor on a separation of the population*

Although those results show that each of the factors have an influence, it does not give any insight on self-organization. Also, what type of motives do the agents have in order to get a split? With these box plots too much information is averaged out. The next results show a more bottom up approach, where is started with the basic scenario, i.e. a group of agents with the same skill values, no favouring and no feedback. From that scenario the effect of each of the factors on the emergence of groups is being studied.

Self-organization with two factors

In the rest of the results the influence of the skill difference, group favouring and feedback on agents having different motives is studied. In order to see how these factors influence different motives, four different situations are considered: Two groups of agents with an achievement or affiliation motive (ach-aff), achievement or power motive (ach-pow), power or affiliation (pow-aff), and mixed motives (mix). The latter argues for no difference between motive profiles between men and women.

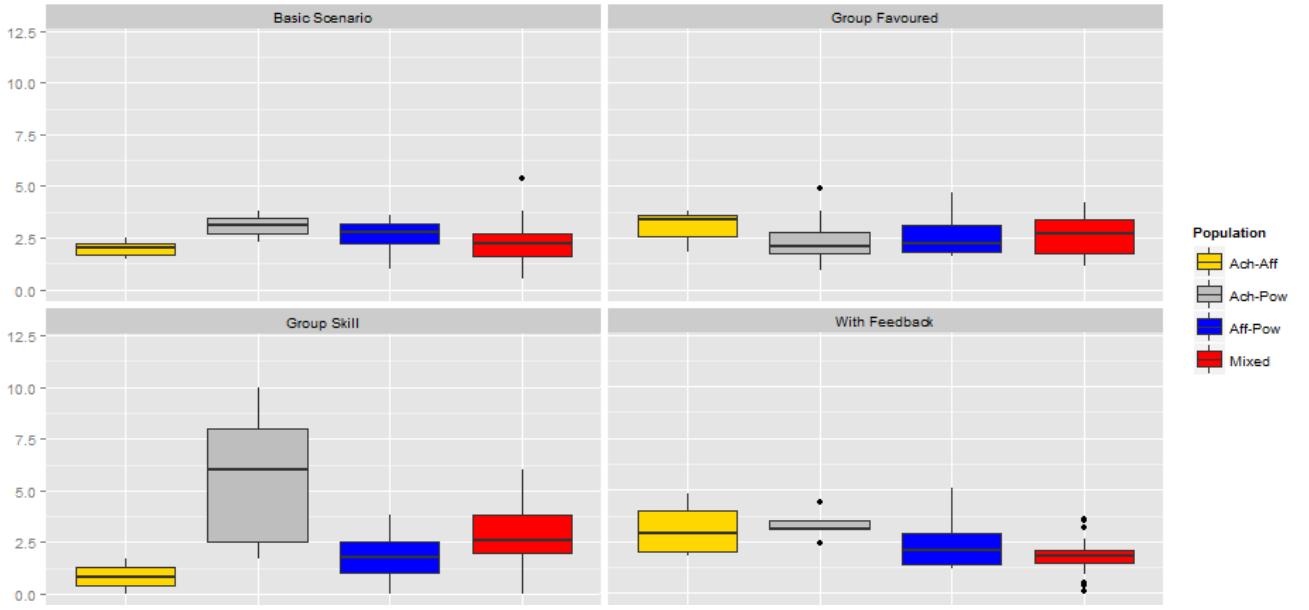


FIGURE 5.11: *Effects of different factors on the emergence of a separation in the population.*

Basic scenario In the basic scenario without any nurture influence no groups emerge. Even the affiliate agents interact with both power and achievement agents. Apparently, without feedback the affiliation need can be satisfied by interacting with other type of agents too.

Group favoured With liking members of one own's group, and disliking the others barely has an effect. For the achievement and power population it could be expected that this would have no effect, since both motives are not much influenced by friendship values. However, also the other populations, where agents high on affiliation are present, the group favouring has no effect. The agents can satisfy

their needs even with the agents of other groups that they slightly dislike. Since the agents high on affiliation also have other needs they manage to interact with those other agents, for instance by learning from them. This result in an increase of well-being and therefore positive friendships afterall.

Feedback Also with only feedback acting on the different motives no seperation in the population is obtained. Remarkable is the fact that it looks like the affiliation agents are able to mix with the other motive-driven agents. An explanation for this might be the fact that the agents can choose their activities, which give the agents more freedom to find an activity where the social needs can be met.

Skill difference The result from a difference in skill between two groups of agents show similar results as those obtained in hypothesis 3. Without any feedback the agents seem to be happy with each other. However, in the case of achievement and power agents having different expertise, the population tends to split. This can be explained by the fact that on one hand the achievement agents want to perform that activity where their skills is the highest, since probability of success is the highest too. On the other hand the power agents do start with higher skill values, but are still able to develop those. Since only the results from the first 15 time steps are obtained, their skill have not yet reached the maximum value. Probably, after some time, the power agents might search for the achievement agents in order to learn a new skill.

Self-organization with multiple factors

In figure 5.4.2 the results of multiple factors acting at the same time is shown. It can be concluded that a combination of multiple factors causes more group splitting behavior. In more situations the box plots reach higher, which argues for a less cohesive group of agents interacting with each other. The most interesting results will be discussed in more detail below.

Group skill and feedback The only population that shows the emergence of two groups in the case of skill difference and giving feedback, is the population with one group of mostly achievement driven agents and one group of mostly affiliate driven agents. These results match with the results from hypothesis 3, where it became clear that skill difference of affiliate driven agents has an effect on the group interaction, but only in the presence of feedback. In those results most of the agent benefited from the affiliate having better skills, except the affiliate towards the achievers and the other way around. In combination with the results from hypothesis 2, where it became clear that a group of achievers and affiliate agents that give feedback to each other are not stable, the results in figure 5.4.2 are not surprising.

Where only group skill makes that a population of achievement-driven and power-driven agents tend to split, when giving feedback to each other this results in a cohesive, interactive group. The skill difference makes that the feedback that is given by agents from the other group are relative higher than the feedback given from agents from their own group.

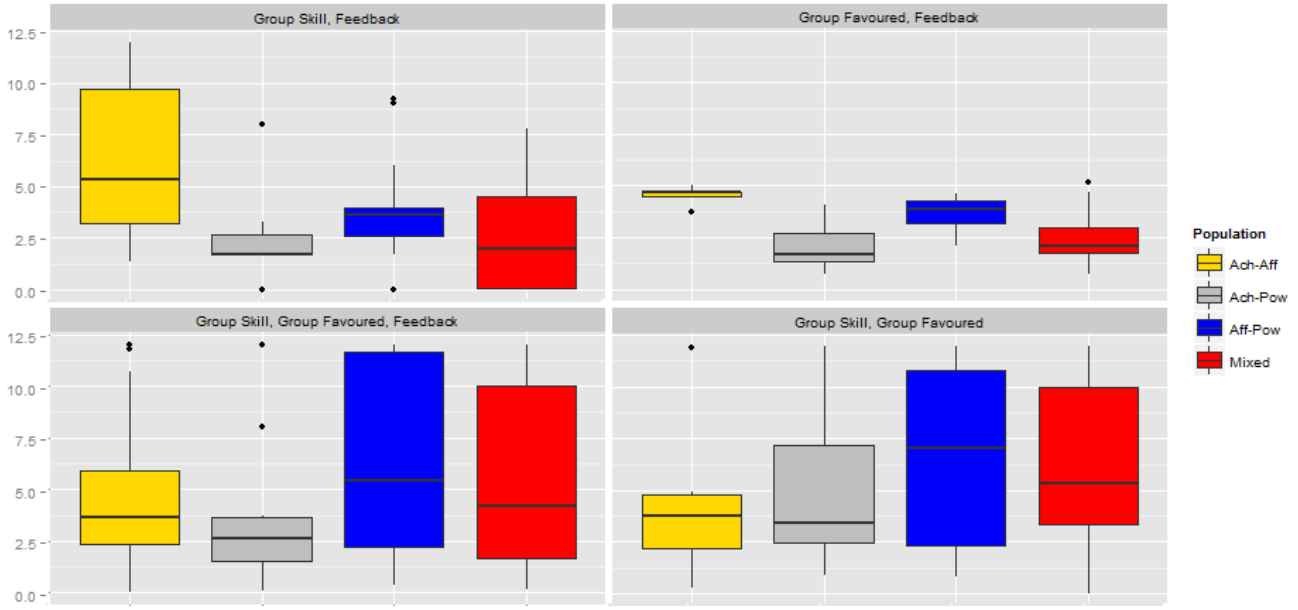


FIGURE 5.12: *Effects of different factors on the emergence of separation in the population by self-organization.*

Group favouring and skill differences The effect of group favouring on the scenario where two groups of agents have different skills is particularly high in the case of an affiliate versus power driven population and in the mixed population. The combination of power agents on one hand, trying to get the maximum value for their skill, and the affiliate on the other hand, disliking those power agents, make that the group stays seperated.

Feedback, group favouring and skill differences Compared with the scenario where feedback is given and a skill difference exists, the group favouring has an effect on the population with affiliate and achievement agents. It results in a lower tendency for a group split, which might be counter intuitive. Since the affiliate are sensitive for the friendship value, one would expect that the group effect would only strengthen the tendency for separation. What makes it the opposite effect, is the fact that the affiliate have a positive attitude towards each other, and give each other positive feedback and the feeling of acceptance. This is a snow ball effect which makes that the affiliate keep participating and keep choosing activities. The effect of positive feedback from affiliate agents is stronger than the effect of negative feedback from the achievers. At the same time, the friendship from achievers towards affiliate might be negative, but both their action choosing as feedback is based on success and difficulty and not on the negative friendship.

5.4.3 Conclusion

From only a difference in needs and the influence of another factor, like skill difference, group favoured, or social interaction, no clear split in the population emerges. The most outstanding results obtained are the scenarios with: 1) Feedback and a difference in skill, where the population with both achievement

and affiliate agents shows a clear split, 2) a difference in skill and group favoured, where both the populations with mixed motives and the power with affiliate agents shows an effect, 3) skill differences, feedback and group favouring, where again a mixed population and power with affiliate agents shows the most effect.

Overall the power with achievement population shows barely a split between the groups in any kind of scenario, except with only a skill difference. This means that with the existence of social interaction the affiliate motive plays an important role in the emergence of the two groups. Furthermore the scenarios with a combination of differences of needs and skills, and social interaction has the most effect regarding a separation of the population. In other words, the effect of a difference in nature combined with nurture influences argues for the role of self-organization in the emergence of the glass ceiling, with in particular the affiliate need having an influence.

Chapter 6

Discussion and Future Work

In this chapter some issues of the model, the playground and the experiments are discussed that came up when analyzing the results and that warrant further study.

6.1 The model

The issues about the model that are discussed are captured in three categories. The first subsection discusses motive related issues, the second subsection captures all points about the action planning of the agents, and in the final subsection some points about the social groups are mentioned.

6.1.1 Motives

The three motives in the model were based on three simple rules that agents could strive for. However, the needs found in people are more complex, and the following discussion points show how this can relatively easily be captured in the model.

Social related goals

The type of actions that the agents can take in order to satisfy their needs are very simple. Also the achievement and power motive are not focused on being social. However, being social indirectly can still help them reach their goals. For instance an agent driven by power wants to increase his chat skill, which can only be done by chatting, i.e. being social. Nevertheless, more social related goals can be thought of, like reaching a certain status in a group or having a number of friends for achievement [20], or teaching others skills and show expert power for the power motive.

Fourth motive: Avoidance

According to [14] a fourth motive can be distinguished, namely avoidance. With this motive people strive to get as less failures or decrease in well-being as possible. Although avoidance is presented as a motive next to the other already existing three, it can be argued that this motive rather act on all other three motives. In [26, 31] each of the needs is split into two components: An approach and an avoidance motive. The approach component is comparable to the way the motives are used in the model: a drive for action. The avoidance component works the opposite, as it drives people to avoid certain actions or situations. The way this avoidance affects behavior depends on which motive is involved. For example, avoidance in achievement expresses itself by avoiding failure, i.e. high risk goals. People with a high need for power will try to avoid situations where one is overruled by others, and affiliate driven people rather evade rejection.

Indirectly these aspects are taken into account in the model. When one of the above described situations occurs, a decrease in well-being makes that agents will avoid similar situations. However, according to [31], a high need for affiliation does not automatically mean that the avoidance component of this needs is high too. Accordingly, instead of three motive values, six motive values should be taken into account, with for each need an approach and an avoidance component.

6.1.2 Action planning

The following discussion points are all related to the way the agents plan their actions. In the model the action planning is relatively simply and for more believable behaviour more concepts are needed.

Setting goals

The agents in the model can only choose a direction of behavior, but are not able to set a goal for themselves. For instance, they can choose to play football, but not that they want to win with at least 3 goals more than the other team.

In [42] it is proven that goal setting has an influence on the belief in one's own ability and the performance. Therefore it should also be integrated in the self-efficacy and computation of the effort.

When the agents are able to set goals for themselves, this can make the behavior more believable in different ways. For instance, the achievement motive can be extended such that it is more realistic. According to [14], achievers not only want to have success, but also set higher goals every time. This would be possible in a goal-setting environment. Also group tasks would be more relevant, when agents realize that certain goals only could be reached with the help of others.

Success and failure

In order to compute the outcome for competence, relevant for achievement, only the outcome 0 or 1 is possible. This represents total failure or total success. However, an activity can be done successfully although the performance is not perfect. In other words, instead of assigning the value 1 to success, a value between 0 and 1 should be the outcome, with 0 no success and 1 perfect performance.

Somehow this is already taken into account with the football game in the computational playground. The result of the match is not just a win or a loss, but also a measure of winning or losing is given, by subtracting the score of one team from the score of the other team. By scaling the result of the match always lies between -1 and 1.

The same kind of computation of the outcome could be used with other type of actions too, where for instance 0.3 with rope skipping means that the trick is performed successfully, but it did not look that good.

A possible way of doing this is taking the effort, difficulty and experience of the agent into account and defining a smaller interval between 0 and 1. The outcome of the action will be laying in this new defined interval. The higher the effort, the higher the interval, and the more experience the smaller the interval.

In this way agents with the power motive can also strive for more certainty, by trying to reduce the size of the performance interval.

Action domain

In the model it is assumed that the agents, in the action planning phase, compute a behavioral intention towards every possible action. In complex environments this would get too complex and is also not realistic. Relatively speaking, people do not consider that many actions either. In a lot of situations people take actions because they are used to do it and are not consciously working out an action plan. This is part of our nature in order to simplify the world around us.

In case of complex environments, agents should have these behavioral characteristics too. For example, agents stay performing the same action, until it becomes clear that this behavior will not satisfy their needs. Only then other actions will be taken into account. Also in that case not every possible actions should be taken into consideration, but actions that are 'closest'. Close actions could be actions that are somehow already familiar to the agent, or are performed by others that are known by the agents.

Probability of success

There are two different kind of probabilities: the probability of being able to do the action, and the probability of succeeding when performing the action. For example, probability of success for rope

skipping can be very high because of having the right expertise, but if all the skip ropes are occupied, this probability becomes 0.

The second one, i.e. the probability of performing successfully, is taken into account with the self-efficacy. However, the first one is not considered at all, at least not directly. Two solutions are possible. The first one is very straightforward, where, for instance, the number of free skip ropes divided by the total is the probability of being able to perform. However, this is harder in a dynamic and complex environment.

A second possible solution would be to not just take the well-being gained by performing into account, but also the decrease in well-being by doing nothing. In that case an agent is able to 'learn' that some actions will be risky to take because it is harder to actually start the performance. It is important though that context is stored with this information about the task. Take for instance the skip ropes again. If all skip ropes are occupied, the agent should link the decrease in well-being to the condition 'six agents are rope skipping'.

6.1.3 Social groups

As mentioned in the introduction, social groups are a complex phenomenon and only a few aspects, like feedback and friendship, were within the scope of this thesis. Although results are obtained, more social related concepts could be implemented in the model in order to get more insight in the emergence of them.

Status and familiarity

With the existence of groups, social status emerges. According to [33] status and power are the main drives behind social interaction and connect individuals to social groups. As mentioned in chapter 4, this is also the drive for action in the model of [13].

Within every group each member has status, which is obtained by social interactions. This concept can be used in the proposed model too. It might not be used as a main drive for behavior, but can still be integrated in the needs. For example, agents with a power motive like to have high status, and achievers might want to achieve a certain status withing a group.

At the same time the familiarity aspect of relations can play a more important role. The familiarity can be set to 1 if agents are in the same group, and to 0 if they are members from different groups. If the familiarity is 0, the status instead of friendship value is used to indicate how skills are, how nice one is etc.

Each motive might interpret these status values differently. According to [37] affiliates feel more rejected by someone with a low status then with a high status. On the other hand, if someone is known a higher quality of friendship is experienced as being worse than being rejected by a less of a friend.

With this status a ranking could be made of the population and a correlation could be found between status and motive.

Social identity

Within each group each of the members has a social identity, and will behave according to that identity. These identities are emerging and depend on the common values of the group.

The same could be used in the model, where an identity is collection of values and norms, like stated in [43]. The agent will act according to this identity, and might therefore switch behavior when changing groups.

The motives will influence these identities, in particular when a group is high on one motive. One group can be focused on social interaction with each other, while another group only wants to win the football match. In other words, when an agent acts in that group, his corresponding motive will be activated. He will mainly satisfy that need, and if he is not mainly driven by that need, he might want to switch to a group where his main motive is activated.

Ingroup/outgroup effect

The in/outgroup effect is an emergent property of social groups, where members of the same group favour each other over others, and in particular dislike non-members. Already a similar effect is obtained, indirectly by group emergence. Because agents interact with each other in one group, assuming the group is stable, i.e. all members gain from being in this group, the mutual friendship will increase.

However, in [1] it became clear that this in/outgroup effect is already present when only assigning people to two different groups, without knowing each other or having interacted. It means that this effect not only emerges from the interaction, it coexists with the groups. Therefore it should be used in the model too.

In the same way that familiarity is used with members of one's own group or not, agents can increase mutual friendships with members of their group, and decrease the ones of non-members. In this way the effect of the social groups is only strengthened.

6.2 The playground

Besides the points mentioned in the discussion about the model itself, some issues about the implementation in the computational playground are considered here.

Football

In the playground the agents are put into two teams randomly. It would be more realistic if the agents were able to select teams for themselves. From all agents present in the football zone two agents could be chosen randomly, being the team captains. Then, one by one, each of the agents could be picked by the captains, based on the needs of the captains. So for example, an agent high on affiliation would choose an agent whom he is friends with, while an achievement driven agent would prefer an agent with a high skill. From this choosing process also groups can emerge. In combination with other social aspect mentioned in the previous section, like adding the in/outgroup effect, within the football field the effect of social groups can be obtained the most.

The games

In the playground almost all activities can meet all three needs of the agents. Only the rope skipping activity does not meet the affiliation need directly. However, the existence of games where one of the needs is not met, will probably influence the emergence of a split in the population.

Group tasks

In the playground football is the only game where more agents are needed at the same time to reach a goal, i.e. at least two agents are needed for both teams. Note that these teams are randomly chosen. The remaining activities are all individual in the sense that, besides a chat partner, no other agents are needed to reach a goal. In other words, there is no game where agents can choose other agents to cooperate.

By letting the agents choose to work together more interesting interplay between the motives can be studied.

Action choosing

When the agents go to chat or rough & tumble, their motivation to got there is only based on the highest BI towards one of the agent being at that activity already. However, when arriving there, that agent could have changed to another activity, which means another chat partner needs to be chosen. Or the agent could accept the request for interaction, but others are accepted too.

In both cases other agents are involved in the action too, although the BI value towards chat or rough & tumble did not capture those other agents possibly staying there.

Therefore a measure should be found that expresses the BI of all the agents together being present in one activity zone. Simply averaging is not a proper solution, since the BI towards the group would be the same both in the case of agents with a low positive BI values, as in the case with one agent having

a high BI value, and another having a high negative value. The BI should mainly focus on the most favoured agent, but also the risk of interacting of less wanted agents should be taken into account.

Probability of performing

As mentioned in the discussion about the model, also in the computational playground the agents do not consider the probability of actually being able to perform an action. This results in agents waiting at the skip rope zone forever. Their need will get higher, but this will only result in a higher BI towards rope skipping.

This can be solved by the solution mentioned in the previous discussion about this problem, or by letting the agents check if there is a skip rope available.

Emergence of the chat activity

In the current model chatting can only be done by the agents in the chat zone, but agents that are waiting to go rope skipping, or watching football should also be able to chat with each other. Then the agents that are watching football would become a chat group itself.

Invitations

For chat and rough & tumble the agent will choose a potential partner from the group of agents that is standing in the corresponding zone at the time of choosing. Sometimes an agent stays playing one game, football for instance, not because he likes it, but because there is no alternative. He might rather chat with one of the agents, but that agent is also in the football zone. At the same time, that other agent might feel the same about doing something else.

Therefore the agents should be able to invite each other for other games. If both of the agents wanting to chat ask each other to go to the chatting zone, different group dynamics would occur.

6.3 The experiments

Within the scope of this thesis the influence of social interaction on the emergence of the glass ceiling was studied. Therefore some sub-questions were used to get insight on group stability. Although the main question has been answered, the experiments did not capture all aspects of the group emergence that could be studied. These issues are discussed below.

Hypothesis 2

Here the influence of the motives on the group stability was studied, where agents were giving feedback to each other. The focus here was mainly on the affiliate motive and it was shown how affiliates do not easily mix with other motives to form a stable group.

It would have been interesting to look more deeply into the dynamics of these groups, and to see what type of requirements should be met so that a proper merge would appear. For example, would skill difference have an influence? Or what would happen if only achievers were interacting with only one affiliate? Or the other way around, would one power agent make that with only affiliate agents a stable group could be established?

Hypothesis 3

During the third hypothesis only the influence of all affiliates having a higher skill is studied. It was relevant for the scope of this thesis, i.e. one of the genders having a specific need plus having better skills than others, but the hypothesis could be studied more broadly.

For example, it became clear that football has a different computational framework than the other games, so it is not legitimate to generalize the results.

Secondly, it became clear during the fourth experiment that with a skill difference between the achievement and power agents also resulted in a separated population. By testing this specific scenario as is done during the third experiment could have given more insight in why this happend.

Hypothesis 4

In the last hypothesis the emergence of different groups of agents was studied. In most of the runs all the agents went playing football, and stayed there. Therefore the game was eliminated from the experiment, because this activity worked as a magnet. The whole set up of the football activity is different than the other games, where agents are put in teams randomly. The random teams make that the agents interact with all other agents, without being limited by negative prejudices. This can have a positive effect for all types of need satisfaction. Also the success is not just 0 or 1 but depends on the number of goals scored.

Besides the elimination of football another aspect has not been taken into account. As mentioned before, in the playground the agents sometimes stayed at one activity, seemingly as one group, simply because there was no option to chat with someone. While analyzing the collected data this type of groups were seen as a stable (mixed) group, with no tendency to split. However, it could be possible that all agents of the same group rather wanted to go somewhere else. The relatively simple rule to distinguish split groups from mixed group did not allow to discriminate these types of scenarios. The underlying reason for a split or mixed group should therefore be studied more carefully.

Finally, the results shown are only from the fifth up and until the fifteenth time step are considered. However, the skills and friendship keep evolving over time and therefor the obtained results might change after a longer time span.

General

The hypotheses that were tested here were related to the emergence of the glass ceiling, i.e. the emergence of a split in population by self-organization. However, more hypotheses where considered, but were unable to test because of the complexity of the data. A proper visualization and analysis were therefore too time-consuming.

6.4 Further research

From the discussion and possible solutions, the following is suggested for future work:

- Extend the model with social related concepts like status and social identities. Not only can this give more insight on the emergence of the glass ceiling, like in [13], but the emergence of social groups and its influence on behavior in general can be studied more broadly.

  With the above extension also status and position in a group can be a goal of the agents. It can make the achievement motive strive more for interaction, for instance by trying to reach a certain position in the group. Furthermore, for the power need more types of power can be considered where status difference plays a role.

  Related research questions can be: How does social status arise from social interaction? Can a difference in social status between men and women support the emergence of the glass ceiling problem? How does having a gender related identity influence behavior? Do certain needs achieve higher social status than others?

- Extend the playground with more activities where for instance a group of agents is needed or not all the needs can be satisfied. In the field of management the focus is on how people with different motives could perform the best in groups. With a proper model more insight on this can be obtained. Related questions could be: What needs do agents have that tend to get a leader position? Are there motives that tend to achieve more when working alone?

- For more believable behavior, the model can be extended with the avoidance aspect in the motives. Also the ability for agents to set concrete goals for themselves should be taken into account, rather than just a direction of behavior. Then the model can be used to study different social related problems where believable decision-making needs to lie in the core of the model.

Chapter 7

Conclusion

The main scope of this research was to study the emergence of the *glass ceiling* and how the existence of *social groups* can cause such a gender separation. The focus was on the interplay between *nature* on one hand and *nurture* on the other hand. We argued that the *self-organization*, i.e. the combination of the biological differences between boys and girls, and the social interaction, would have the biggest impact on the splitting of a population in the glass ceiling problem. Since this problem is an example of a collective system, a *multi-agent based simulation* was used. In this way a clear distinction is made between the interactions on individual level, i.e. the micro level, and the emerging collective behavior, i.e. the macro level.

To answer the main question, a computational playground was build where agents represent children that are able to choose games to play. The model that is used in the computational playground has two main requirements. Firstly, the agents in the model should show *believable decision-making*. Secondly, the model should provide *social* aspects in the framework of the agents, in order to study the effect of nurture. A combination of the two requirements is hard to find in already existing models. Therefore a new model was needed, in particular one for implementation in a multi-agent based simulation.

The proposed model in this thesis was build around the need theory of McClelland, in which the need for *achievement, power*, and *affiliation* are stated as being the basic drives for action. In order to take existing conjectures about the emergence of the glass ceiling into consideration, three other concepts where integrated in the model: (1) *Skills* for the agents to test the influence of natural differences between children, (2) social *feedback* representing both verbal and non-verbal interaction between people in order to study the influence of nurture, (3) *friendships* which enables the agents to build and maintain relations with each other. Both the second and the third concept depended on the personal motives of the agents.

Before getting to the main question, the playground was used to test some hypotheses as sub-questions to get insight on the behavior of the agents. In particular, how agents driven by different need interact with each other, or tend to avoid social interaction. The following results were obtained. First of all, by letting the agents give each other feedback on their performances, their behavior changes with respect to both motives of the surrounding and the performing agent's itself. Hence, the combination

of motives in the group is significantly influential, since everybody wants to perform tasks that satisfy his needs the most. Secondly, the effect of the motives of the agents on group interaction was tested. We showed that overall a group of agents high on power or high on achievement is stable as a group, while affiliate agents drop out one by one. Moreover, the combination of agents high on achievement or power together results in a stable group, in contrast to affiliate agents together with other agents. Accordingly, it can be concluded that in a setting where all agents have the same skills and give each other feedback the affiliate are not the first ones to form a group.

The third and final sub-problem focused on mutual friendships. We showed that with a mixture of achievement, power and affiliate agents, giving each other feedback, particularly the affiliate agents had a negative attitude towards the other agents. Only when the affiliate agents had better skills these attitudes were positive. Even the relations between power and achievement agents were better. These results were not obtained when the agents did not give each other feedback. Therefore, it can be concluded that agents high on affiliation need to attribute something extra in the group, i.e. having better skills, if they want to be able to satisfy their needs when interacting with other need-driven agents.

Based on the three above findings, the influence of social interaction between agents with different motives and skills on the emergence of a split in the population could be studied. Two types of simulations were done. On one hand all possible influences, both nature and nurture, were tested separately and on the other hand the combinations of these two factors were tested, to see the effect of self-organization. Each simulation started with two groups having different motives and skill values, representing the natural influence. The objective was to see if this on the long run would result in a separation of the population. However, this did not result in the emergence of two different groups. Next, the effect of nurture was tested by letting the agents give feedback to each other, and starting with a group favouring, i.e. liking agents of the same group and slightly disliking the others. On a group of agents with the same skills but different needs, this again did not show any effect on the emergence of two groups. Finally the combination of nature and nurture was tested. Here a clear effect was found, i.e. two groups emerged. In particular the combination of the two groups having higher skills in different expertise, and a mixed population mostly driven by achievement or affiliation showed the emergence of two groups, but only when also feedback was given. Besides that, the situation with a population mostly driven by power or affiliation, and again both having different skills, showed a clear split, but only when the agents were group favoured. In both situations the two groups were split based on their motives and skill expertise.

Based on the results of the simulation of the playground two important conclusions can be drawn. First of all, it proves that a biological difference itself does not cause a split of the population. The presence of social interaction however amplifies the effect of these differences and results in the coexistence of two social groups. Secondly, the affiliation motive played an important role in the group split. In almost all situations where two groups emerged, one of the groups was high on affiliation. However, these results were only obtained with the presence of both differences in skill and social interaction. If the conjecture about women having a slightly higher need for affiliation than men is true, the results argue how affiliates are sensitive for the social interaction and make that two groups emerge.

Therefore, we argue that the self-organization plays an important role. In other words, we believe that biological differences between men and women (nature) has not enough effect to cause a gender gap. However, by acting on these differences and emphasizing them (nurture), it results in two different groups, i.e. men and women, that are treated differently.

Overall this thesis proves how a social related problem can be studied by using a computational model. In particular, how questions about the effect of social interaction on a society can be answered.

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