A Simulation of Cognitive and Emotional Effects of Overcrowding

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Abstract

To explain complex forms of human behaviour it is necessary to take into account the interaction of cognition, emotion and motivation. In this article we show that it is possible to predict why and how crowding alters cognition, emotion, and motivation. An artificial population of autonomous agents (the “mice”), lives and grows on an island, explores and conquers it. When the population grows above a certain limit, all symptoms of crowding emerge, which can be found in human groups too. The rate of aggression increases, but the tendencies to tighten the network of social relations as well. Fear arises and this produces a specific form of cognition, namely rough perceiving, rough planning and a loss of persistence of behaviour (“behavioural oscillation”). Groups of humans under crowding conditions correspond in pattern.

Introduction

It is impossible to explain even moderate complex forms of human behaviour only by cognition. It is necessary to take into account the motivational and emotional state and the changes of these states. Different motivations and different emotions mean different cognitive processes, different forms of thinking, remembering, perceiving. A participant in an experiment on problem solving will think in a different way, if his motivation is to impress the pretty experimenter than if it is only his intention to collect credit points for participation. These differences in the cognitive processes can be dramatic and it is not recommendable to study cognitive processes without considering the underlying motives.

The effect is even more dramatic with respect to emotions. During a problem solving process emotions will change nearly for every subject – often within minutes! First there might be a high degree of success expectation. This means a high estimation of self efficacy or competence. Then after some unsuccessful attempts, the experimental subject's success expectation will decrease and he will become angry. In anger however thinking-processes take another shape (see Abele-Brehm, 1986). – Then there might be a slight progress towards the goal and the subject may believe, that it now will be able to solve the problem. The result is pride and this again means a different form of thinking, characterised, for instance, by inexactness and superficiality. – If the emotional impact is not taken into account it is not possible to get the right idea about the thinking process.

We will now show, how a theory about the impact of emotion and motivation on action regulation may look like. To test this theory we studied the development of a population of artificial animals (the "mice"), designed according to the theory and investigated how behaviour changes with the growth of this population.

Action Regulation

Fig. 1 shows a rough sketch of the theory of behaviour-organization of a "mouse". On the left side a flow-diagram with the different processes of action-organization is visible. It shows a cycle of processes, which begins with perception, resulting in an "image of the situation". This is extrapolated – according to the knowledge the mouse has about the laws which govern the respective domain of reality – to an "expectation-horizon". The conditions of the actual situation, the expectation of things to come, the state of the Motivation-System and the actual knowledge about suitable actions are the inputs determinig the choice of an actual motive, producimg a data-structure called "intention". An intention is an important part of the working memory; it answers the question "What should be done and how?". This intention – together with the knowledge about the rules governing the respective domain of reality, are the input for the search or constrruction of an suitable course of actions, called "plan". If a plan can be found in longterm-memory or can be constructed, the plan will be run. If by running the plan the system gets to a goal, a suitable final consumptory action is activated, which normally alters the state of the motivation-system. (The third column of fig. 1 – "measurement of competence", "measurement of certainty", etc – will be explained below when the emotional system will be described.)

How does the motivation-system looks like? Fig. 2 shows the basic ideas. The Motivation-System basically consists of a number of tank-like structures. An organism's energy store or water store can be considered as a "tank". This tank empties in the course of time by consumption (dependent on basal metabolism and the activity of the organism). The tank has a set point and should be kept at this level! Is there a setpoint-deviation, a need arises, which will be the basis of a motivation. For each tank there exists a need-indicator (NI), the activation of which is dependent on the extent of the deviation. A motive is a need plus knowledge about the goals (situations, objects) an organism should strive for to satisfy the need (not depicted in fig.2). Goals and paths which lead to them, can be learned. (This is not the Lorenz-tankmodell of motivation. A strong need means a full tank with Lorenz, but an empty one with us!)

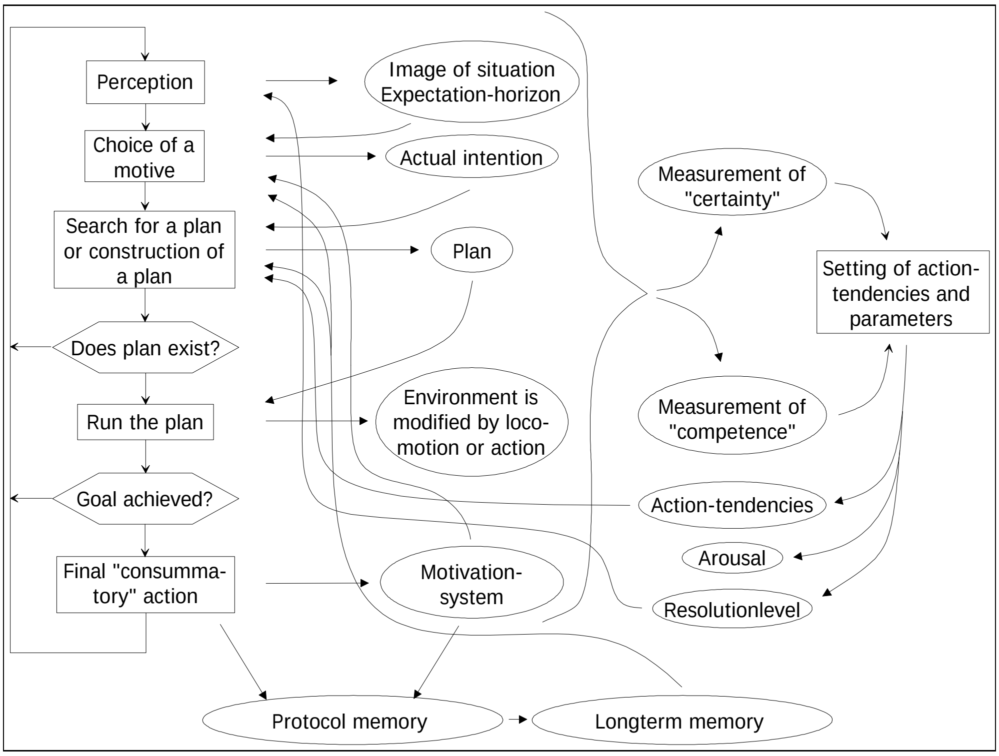

Fig. 1: The mouse' action organisation and data-structures. See text.

Six "tanks" can be found in a mouse. First there are tanks for "existential" needs; hunger (need for food or energy), thirst and pain (need for an organisms intactness) being the most important. A pain-indicator signals, for example, that a component of an organism is hurt (the "tank" of structure-intactness deviates from its setpoint). Very important are "tanks" for affiliation (need for group-binding), certainty (need for predictability) and competence (need for mastery).

The affiliation-tank is filled by "signals of legitimacy" (as Boulding, 1974, p. 173 called them). Such signals indicate that an organism is accepted as a member of a group and can expect help and assistance. A smile or body contacts (tenderness) may be the most important signals of legitimacy for humans. Signals of legitimacy establish or reinforce friendship. Friends help each other; for instance they launch counterattacks if a friend is attacked by another mouse. – The need for certainty is a need for predictability of the course of events and the effects of ones own actions. The "certainty-tank" is filled by accomplished predictions, whereas it is emptied by events which are new or unexpected or unclear.

The competence tank is filled by successful actions (by internal successful actions, as planning, too) and emptied by failures. The competence and certainty tanks are especially important for emotions, as we will see.

If a setpoint deviation is found with one of the tanks, the organism will try to reduce it. For this purpose the organism looks in its memory for a plan (a series of actions) to a goal, to a way to satisfy its needs. If this is not successful it will try to construct a new plan or it will behave according the maxime "Trial-and-Error".

Many tanks can be found in an organism and hence it is quite normal that not only one but several tanks show a setpoint-deviation at the same time. An organism is in a continuous conflict between different needs. What should one do: Care for food or for water? Organisms are "multistable systems" as Ashby (1990 p. 16) called them, meaning that they have to care for multiple homeostasis. There should be a device for the resolution of such conflicts. For this purpose the expectancy-value principle could be used. The motive with the highest product of expectancy of success and value of need satisfaction is selected to control behaviour. – The expectancy of success is dependent on whether the organism knows actions (or feels competent to find or construct such actions) which result in progresses towards the goal. The goal is a situation in which the respective "tank" can be refilled. A bakery for instance is a goal if hunger is the actual motive. If an organism knows how to reach a bakery, the "expectancy of success" is high.

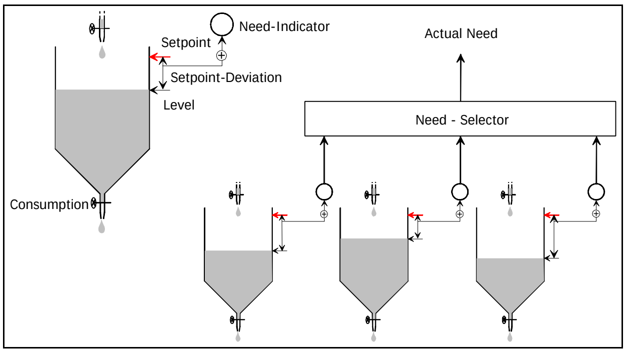

Fig. 2: Needs, motives and motive-selection

Additional to the knowledge of actions an estimation of general competence should play a role in determining the expectancy of success. Higher order organisms are a good many times confronted with problems for which they do not know a solution. In this case they should rely on their general ability to find or construct a chain of actions (locomotions or manipulations) to approach a goal. Planning and thinking, but also such primitive methods as trial-and-error, might be appropriate for this purpose.

The "value" of a motive is dependent on the extent of the setpoint deviation and on a need specific factor. This effect might be maximal for existential needs. Certainly this factor should be high for pain, hunger and thirst.

The product of success expectancy and value we call "motive strength". The selection of the motive which governs behaviour is continually recalculated so that another motive can take over control every moment. However there exists a "selection threshold". If a certain motive controls behaviour it is not enough for another motive just to be stronger than the hitherto governing motive. It should be stronger than the motive strength of the governing motive + a selection threshold! This – to a certain extent – hinders "behavioural oscillations", which can be harmful to the efficiency of behaviour.

The Motivation-System of a mouse consists of 5 tanks with setpoints. Additionally there is a selection-device which selects an actual need, using for this purpose the expectancy-value - principle in the above mentioned form.

How to Simulate Emotions?

Emotions are often considered independent psychic functions or modules. In our eyes such a conception is not very fruitful. We prefer to conceive emotions as *modulations* of cognitive and motivational processes.

What does that mean? Let us take anger as an example. Anger is: high degree of arousal, superficial perception, superficial and (therefore) quick planning, high readiness to act with strong effects (leading often to aggressiveness), hence a tendency for unreflected and risky behaviour. That means that anger does not influence thinking but that anger is a special form of thinking (and perceiving and acting). – If all the above mentioned tendencies are removed, not "pure" anger remains, but nothing. Anger is thus not a factor which "influences" thinking, but it is a special "colour", a specific modulation, of thinking and perceiving and other cognitive and motivational processes.

Fig. 3 shows a sketch of the emotion theory. On the left side two "tanks" are visible, the levels of which represent the extent of certainty and competence which the organism experiences. (These levels are the "measurements of certainty" and "measurement of competence" of fig. 1.) The activity of the "motivators" NI (NI[comp] and NI[cert]) in the formulae in the ovals) represent the need for certainty and competence, which are dependent on the extent of setpoint-deviations of the respective tanks. These motivators trigger a lot of action tendencies (saveguarding-behaviour, aggression, flight, etc.) and parameters (as arousal and resolution-level) which determine the form of information processing, the forms of thinking, perceiving and other cognitive processes. (The mathematics of the emotional regulations is slightly modified compared with Dörner, 2003.)

Emotional regulations are based on the levels of the certainty- and competence-tank. Action tendencies and parameters are dependent on these levels as indicated by the formulae in the ovals.

To become familiar with this theory the best is to consider an example of th calculations: For instance if the competence- and the certainty-level are low (meaning high activities of the need indicators NI, for instance NI[cert]=0.6, NI[comp]=0.7), the rate of safeguarding behaviour will be rather high, namely 0.62 (=0.6 * 0.7 + 0.2 (= person[SafeGuardBas], a person parameter for the basic rate of updating)). A high rate of safeguarding behaviour means frequently updating the "image of the situation".

With the same parameters you will get a relatively high value for flight-tendencies (= 0.6 * 0.7 =0.42) and a low value for aggressive tendencies (= 0.6 * (1-0.7) = 0.18).

This means that low-risk actions will be preferred when looking for a plan or constructing a plan. "Cautious", defensive behaviour will be observed.

Arousal will be rather high; for BasArousal = 0.5 and ArousalWeight (person-parameter) = 0.5 we will get an arousal-value of 0.74 (0.5 + 0.7^2 * 0.5). Exploration tendencies will be low, namely 0.21 (0.7 * 0.3). And the resolution level will get a value of 1 - Inhibition = 1 – 0.74 * 0.85 (Inhibweight: a person parameter) = 0.371. This is a rather low value, meaning superficial perception, superficial planning, hence a high tendency to neglect conditions for action, side- and longterm-effects.

With one word: we get a state of anxiety, a state with high arousal, however relative fearful behaviour (high rate of updating the image of the situation, "cautious" actions (because of the flight tendencies)), a low resolution level and hence superficial perception and thinking.

Emotions as modulations are adjustments of thinking, perceiving and other cognitive and motivational functions to the relation of an organism to its environment. Cognition and motivation is adjusted according to the certainty, the ability to predict the course of events and ones own actions and accordingly to the competence.

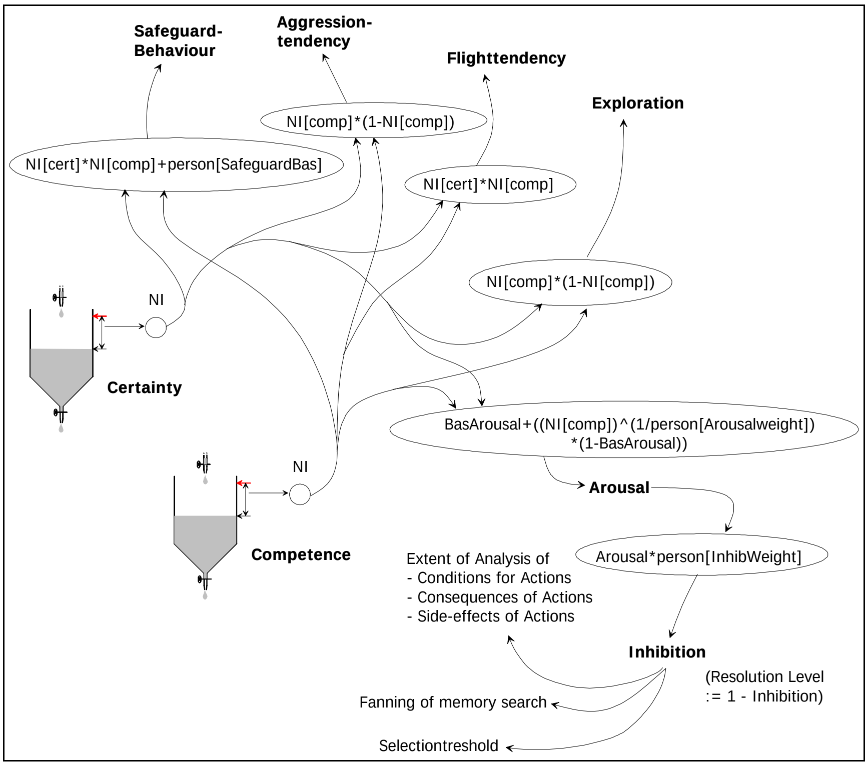

Fig. 3: Emotional regulations.

The estimations of certainty and competence, which are represented as levels of the respective tanks, provide important information about the organism's relation to its environment. According to the respective state of these "reports" the behaviour and the inner processes are shaped; that is this theory's central idea.

The Mice

To test the theory of the interaction of cognition, emotion and motivation we investigated the behaviour of mice-populations, i.e. the behaviour of artificial, computer-simulated autonomous agents, constructed according to the theory. To simulate populations instead of single individuals is necessary since a lot of emotions have a social background or a social function. – More or less large numbers of mice can live within a computer simulated environment and we studied the behaviour of these agents to find parallels to human behaviour. In the experiment to be reported here we studied the effect of *crowding*.

The mice are not immortal, they die after a certain lifetime. They can be killed however by their co-mice too, or starve when they do not get enough food. – On the other side the mice generate offspring. At the moment this is done by parthogenetic cloning. A newborn mouse inherits the genome of the "mother", with some random variations ("mutations"). So we can study the development of the psychic characteristics of the mice in the course of time; the mice populations adapt their psychic attributes by mutation and selection to the ecological niche they are living in. – There are genes for the weights of the needs in the genome of the mice. One mouse might have a very strong competence drive, another a weak one. Additionally there are genes for the weights of emotional regulations. For example there is a gene for the arousal weight. If the arousal weight is low the mouse will stay relatively "cool", even in stress-situations. With a high arousal weight however the mouse will display a tendency to react very strongly to an aversive situation, e.g. with violent outbursts.

Other genes concern physical strength and cognitive abilities, for instance rate of forgetting, the resolution of cognitive processes, that is the resolution level of planning and perceiving. – The reason for this genetic variations is to investigate the development of personality characteristics, especially the temper characteristics. Shall we discover, that in the course of time the mice develop those temper types described by Hippocrates?

In the experimental work reported in this article the development of psychic attributes is only a side aspect. Experiments to investigate the development of psychic attributes have yet to be done.

Fig. 4 shows a small part of a reality domain the mice live in. There are areas where the mice find food (F). Other areas are waterholes (W) where the mice can drink. A third type of areas are dangerous areas (D) where the mice may be hit by rocks ore stones. And then there are "healing swamps" (H) where the mice can cure their wounds for instance when they have been hit by a rock or bitten by another mouse.

At the beginning of an experiment the mice do not know the environment; they do not know where to find food or water and therefore they have to explore the environment. By exploration and learning a mouse builds cognitive maps of her environment within her memory. These maps are visible in Figure 4 as lines with dots. These lines indicate the memory of a mouse, the memory of landmarks the sequence of which forms a path to a goal.

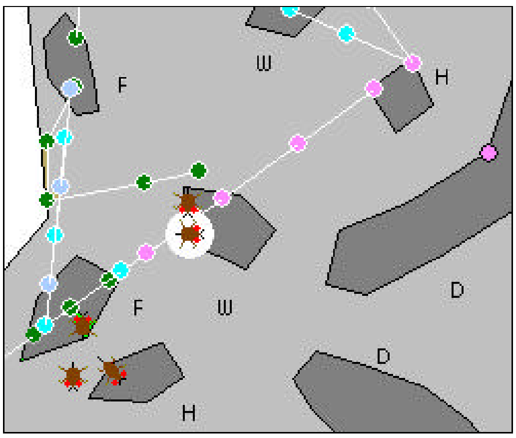

Fig. 4: Mice in their reality. W: Water, F: Food, H: Healing, D: danger.

Young mice are "educated" by their "mothers". The "mothers" teach their "daughters" how the environment looks like by transferring parts of the cognitive map in their memory to the memory of the young mice.

With time mice learn who are their friends and enemies. One should rather say: they make friends and enemies. This kind of social relations will be important to determine their behaviour towards some groups. They will be kind to friends, help and support them, give them legitimacy-signals, and won't bite them (in the majority of cases). On the other side, they will be rather inclined to bite enemies in the fight for food (in case an enemy is an obstacle on the mouse's way to a need satisfaction).

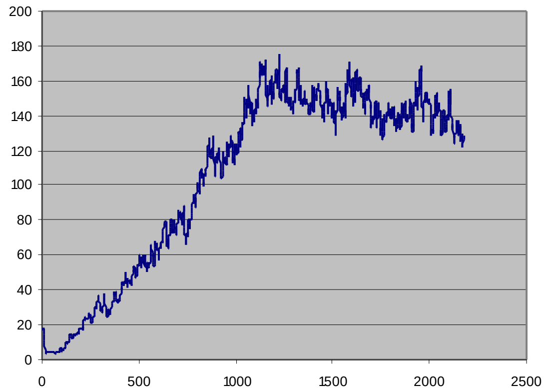

Fig. 5: Population growth (abscissa: time in 100 cycles; 500 means 50000 cycles of simulation; ordinate (??): absolute number of mice).

Crowding in a Mouse - Population

We brought a genetically homogeneous, small population (18 mice) to a large environment and observed the development of this population. The mouse population grew and in the course of time they conquered the whole "continent". Fig. 5 exhibits the growth of the population.

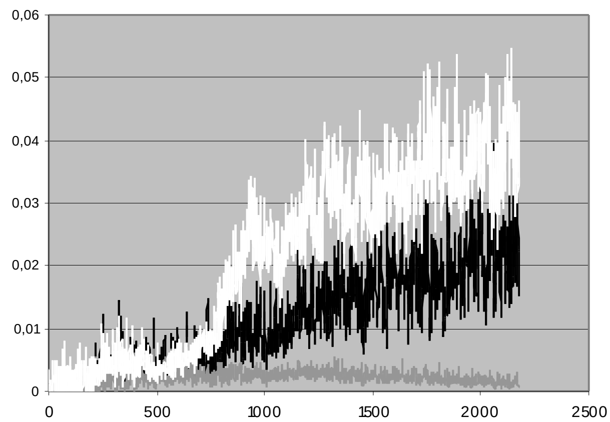

Fig. 6: Relative number of aggressions (black), flights (gray) and affiliative activities ("smiling", white).

The population first decreases, as most of the mice starve because they cannot acquire sufficient knowledge about the environment to find food and water in time. Then however the population grows and reaches a maximum of nearly 180 mice. Afterwards the population shrinks again. The reason for this development will become clear below.

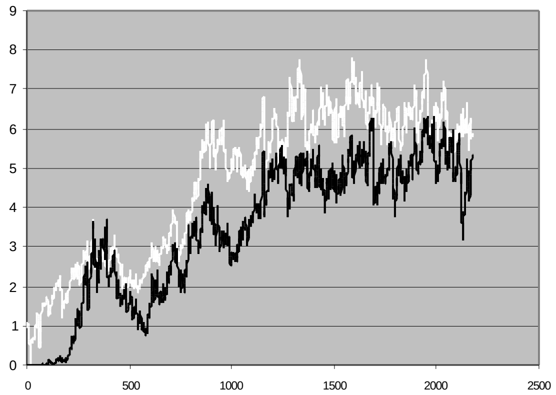

Fig.7: Average number of friends (white) and enemies (black).

The reason for these behavioural changes is crowding, i.e. too many mice for the resources of the domain of reality. The fight for resources generates an increase of the readiness to attack others and in the same time a tendency to look for friends, which could help against enemies. This is the reason for the increase of affiliative activities ("smiling”) when the population grows (Fig. 6). (The slight decrease of flight-activities after 1500 cycles is due to the enlarged number of friends.) In the course of the population growth the mice behaviour changes. In fig. 6 the development of the relative frequency of aggressive and affiliative activities is depicted, additionally the number of flight-movements which occur when the mice are bitten by others or when the extent of fear (expectation to be bitten by others) exceeds a certain level (mean level of fear is depicted in fig. 8).

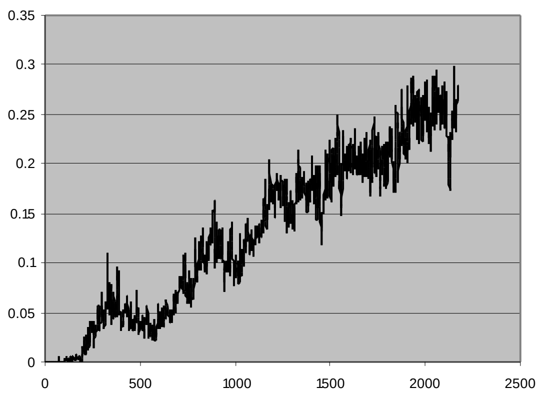

Fig. 8: Level of fear.

It is obvious from fig. 7 that the number of friends and the number of enemies too grows with the development of crowding. Friendships are due to affiliative activities; friends help each other. The number of enemies increases with the number of aggressions.

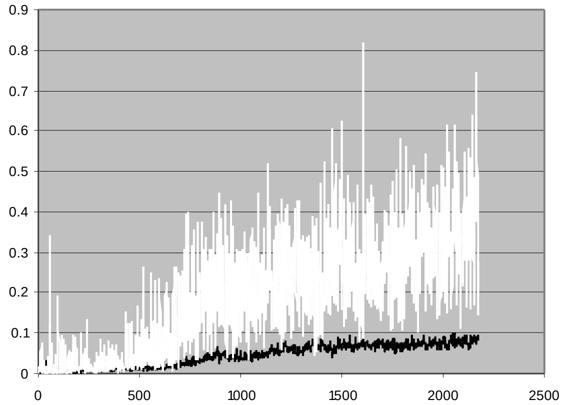

Fig. 9: Relative frequency of overlooking other mice (white) and landmarks (black).

As there is no "aggressive drive" (such a drive was postulated by Lorenz 1998 for men and animals) the tendency to become aggressive firstly is "instrumental”. It serves to remove obstacles when approaching a goal. But the mice can learn that successful efforts to aggress others enhances the feeling of competence (as every successful action) and therefore aggressiveness becomes an instrument to increase the "feeling of competence".

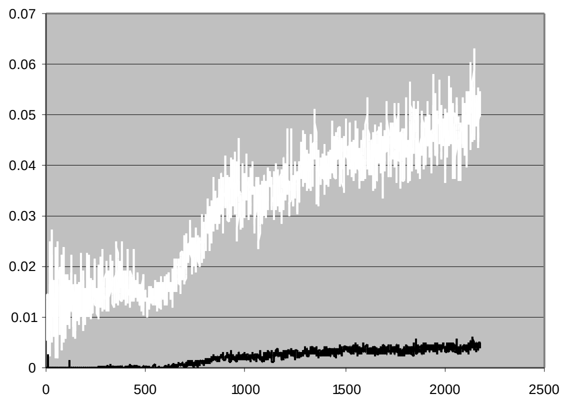

Fig. 10: Relative frequency of motive changes. White: change if another motive becomes stronger, black: change if an opportunity to satisfy another need occurs.

The increase of aggressive and affiliative activities are not the only effects of crowding. Additionally cognition changes. For instance because of the high rate of arousal in the crowded areas the cognitive processes loose their fine resolution and become rough and superficial. Fig. 9 shows the number of mice which are not identified because of the roughness of perception and the number of goals (landmarks) which are overlooked for the same reason. With increased stress the mice loose their ability to orientate themselves in their environment.

Additionally the relative number of changes of the action-guiding motive increase (fig. 10), which produces a decrease of persistency of behaviour. That means that the behaviour of the mice becomes more and more "ad hoc".

Crowding with Humans

Stokols (1972, 1979; see also Freedman 1975, Streufert, Nogami & Streufert, 1980) identified the following emotional and cognitive reactions of human groups to crowding:

- Violation of expectancies regarding social behaviour.
- Anger, tendency for aggression increase.
- Fear and flight – tendencies emerge.
- Persistence of behaviour decreases.
- Trials to improve the coordination with others.

All these effects can be observed with the mice too!

- The attacks of other mice are not expected and appear as a negative surprise.
- These attacks produce an increase of arousal and hence a decrease of resolution level. Therefore perception becomes rough and the mice overlook objects and other mice.
- For the same reason the fear level of the mouse-population increases which produce an increase of flight reactions.
- The persistence of behaviour decreases; this is visible in the increase of the number of changes of the momentarily action-guiding motive (fig. 10).
- The number of friends increase. This is due to the increase of the number of affiliative activities ("smiling") of the mice (fig. 7).

We got these results on the first attempt without any adjustments of the model to the results of crowding research in human populations. Therefore we consider these results as a validation of the theory, especially as a validation of the "emotional" part of this theory.

It is quite interesting that even within the rather short period of simulation some genetical effects can be observed. There is a development to increase physical strength. Additionally the arousal weight gets larger values and the range of sight shrinks! The last mentioned effect may be due to the decrease of the fear level (Fig. 8) which correlates with the decrease of visibility range. The mice with a low vision range don't see so much enemies and therefore live more relaxed.

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