Creating a dynamically stable system in an agent based model using two contrasting modes of cognition

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Abstract

Cognition is a complex concept, many things have an influence on how we think and interact with our environment. Recently, a theory was developed regarding two contrasting modes of cognition, as framework for all cognition. The first mode is the coping mode, in which agents are inclined to make decisions that are focussed on their personal pressing need-fulfillment. The second is the co-creation mode, in which agents tend to direct their behaviour towards creating and maintaining an environment in which pressing needs are less likely to occur. According to theory, these two modes constitute what is known as core cognition, and they are present in every type of society, be it human or bacterial. This paper discusses a model built to test if, and under which conditions, it is possible that a multi-agent simulation will converge to a dynamically stable situation if it is populated by agents of both modes. The implementation is in NetLogo. Results showed that under many possible settings, the system converges to the same ratio of coping versus co-creation agents, and will remain dynamically stable from that point onwards.

Introduction

What is cognition and how does it influence society? Why is it relevant to ask ourselves this? Cognition is the way we think, which determines the way we act. The way we act influences our surroundings: the environment around us as well as the people sharing that environment with us. This makes it important to study cognition.

Theory

Modes of Cognition

Research has been aimed at core cognition, defined by 'the two modes of cognition that underlie human behaviour' (Andringa, Van Den Bosch, and Weijermans, 2015). This paper can be seen as a follow-up of one of the themes discussed there. Andringa et al. (2015) define the two modes of cognition as follows:

> The coping mode exists to address pressing needs and is a way to survive on the short term. The co-creation mode is prominent whenever all pressing needs are satisfied. It exists to explore the opportunities of the habitat and co-creates an environment in which the emergence of pressing needs becomes less likely.

They arrive at these definitions from definitions of the enactive approach to cognition (Andringa et al., 2015; Di Paolo, Rohde, and De Jaegher, 2010; Froese and Ziemke, 2009). The enactive approach consists of many core concepts, a few of which we will discuss here.

The enactive approach is used as basis to describe the idea of an environment which is capablable of maintaining itself. Such an environment needs a living entity that interacts with the system, a 'self'. To function to its best potential, a 'self' should have agency, the ability to actively control and select actions appropriate to the current environmental challenges (Di Paolo et al., 2010).

Andringa et al. (2015) also state that 'life is about need satisfaction'. When an entity exists in an environment and needs material throughput, and is actively behaving to achieve said throughput, it can be said that the environment contains life. Within the boundaries of the environment, the agent is hampered by the necessity of achieving its needs (Di Paolo et al., 2010). This need-achieving is possible following one of two mutually exclusive strategies: the strategy of fulfilling each particular need as it becomes pressing, and the strategy of creating conditions which make it as easy as possible to achieve all needs. The first is labeled 'coping', and the second 'co-creation'.

To elaborate: in the coping mode the focus lies on satisfaction of pressing needs. In doing so, agents in the coping mode show behaviour that is essentially conservative, because they tend to prefer known solutions for known problems (instant need gratification) to the possibility of a better solution that might also not give them the fulfillment they seek at that moment. What they strive for is control over the situation and they feel a strong need for certainty.

In the co-creation mode the focus lies on prevention of pressing needs. To achieve this, cocreating agents will mainly show behaviour that aims to further the circumstances of the environment and as a consequence, benefit themselves. They focus on discovering new possibilities in the environment they live in. Co-creatiing agents strive for the prevention of problems and the creation and maintenance of a balanced system that yields long-term benefits to the agents residing within.

Agents in both modes of cognition are concerned with acting so as to further their probability of a most advantageous future. However, what constitutes a proper action differs between the different modes. When co-creating agents interact with the environment, they improve it for every agent in it, including the coping agents, whereas coping agents may by misunderstanding the surroundings execute an action which is deleterious to the system, but offers short term benefits for them. Agents in the co-creation mode have a more complete understanding of the system, and can thus assess what the best action is for the system. A coping agent does not have this understanding and can therefore be seen as an agent that failed to achieve the co-creation mode. Take note: this is not to say that coping agents are necessarily 'bad' or 'unintelligent', they are a victim to their own reduced understanding. The more developed ones understanding, the better one can oversee the consequences of their own behaviour or themselves and their own environment (Andringa et al., 2015).

The Global Change Game

In 2002, an experiment was done regarding right wing authoritarians and their ability to cooperate in a game named 'the Global Change Game' (Altemeyer, 2003). In this, they collected participants and divided them over groups depending on their conformation to the attributes of right wing authoritarians and tested if these groups were capable of maintaining a stable environment. In an earlier research Altemeyer (1994) outlined what he discovered to be characteristic for right wing authoritarians (RWA's) (Altemeyer, 1994). He defined it as the covariation of three attitudal clusters: authoritarian submission, authoritarian aggression and conventionalism. These are further explained as follows:

Authoritarian submission is classified as the high degree of submission shown towards the perceived legitimate authority.

Authoritarian aggression is defined as the high level of aggression that is exhibited towards various persons, understood to be licensed by the established authority.

Conventionalism is explained as the fierce faithfulness to the acknowledged social conventions endorsed by the established authority.

Andringa (2015) made a connection between authoritarianism and the coping mode. They stated that the two are different words for the same concept, and that it is not lack of intelligence, but the authoritarians underdeveloped understanding of the world that limits their ability to deal with its complexity. Authoritarianism seems a political-level indicator of low long-time viability with an associated focus on (compensatory) strategies resulting from the logic of the coping mode (Andringa et al., 2015; Andringa, 2015; Andringa, van den Bosch, and Vlaskamp, 2013).

In the experiment the Global Change game is played twice, once by a group of people who score high on the RWA ranking scale, and one with people scoring low. The game is a simulation of the earths future, usually involving 50 to 70 players who are assigned to various regions on a large map of the world. The players can be seen as the 'leaders' of the states they are on, and make choices for that state as were they ruling there.

The high RWA simulation produced a nuclear holocaust that killed everyone and destroyed the planet. When the players were given a second chance to make a better world, conventional wars still broke out, and global problems of overpopulation, hunger, and disease went unaddressed. After 40 years, not counting the nuclear war, 2.1 billion people had died, according to the formulae used in the game to take into account the consequences of war, long-term unemployment, malnutrition, and poor medical infrastructures. Comparatively, five times as many citizens had died during the high RWA game as during the low RWA game that was played following the same rules.

This experiment shows that on their own, RWA's cannot create a resilient environment. From this we can infer that the same will hold for agents in the coping mode, as coping mode and authoritarianism are similar. Subsequently, we can say that non-authoritarians, or agents in the co-creation mode, are per definition capable of sustaining an environment.

This Paper

If we combine the theory of the modes of cognition with the practical example of something similar to the Global Change game, the following questions arise: Can the two modes of cognition exist together in a stable manner and can they uphold a dynamically stable environment? This is what was asserted by Andringa et al. (2015). If that is the case, do any other conditions need to be met? According to Andringa et al. (2015), these modes of cognition should be generic for all life forms, so they should deliver constraints pertaining to the stability of life. It should be possible to use this to investigate within which borders life (the environment including the resident agents) can be dynamically stable.

This breaks down into two parts. The first is: can the agents maintain their existence (or do they all die)? The second part is: can the system remain stable? Together, that becomes: if the system is maintained in the most optimal way, does that create the possibility of increasing the carrying capacity of a system?

This leads us to the following research question: "Can agents that are defined on a spectrum from coping to co-creation exist in dynamic stable equilibria with their environment. If so, under which range of conditions?"

To investigate this we will implement an environment in Netlogo, a multi-agent programmable modeling environment, in which agents, defined by either a coping or co-creation strategy have to fulfill a number of simple needs in order to stay alive.

Model

This model description follows the Overview, Design Concepts and Details + Decision Making (ODD+D) format described in Müller et al. (2013); Grimm et al. (2006). We start with a general overview of the agent-based model, followed by explanations of the designs concepts. At the end we will discuss the details of the model.

Overview

Purpose

The purpose of this model is to test whether implementation of the cognition model described by Andringa et al. (2015) and in the above theory section can result in a dynamically stable environment. We implemented agents who can switch between two cognitive strategies. In combining both types of agents in an environment where they have to fulfill several basic needs and by monitoring the agents, we can judge the dynamic stability of the set of agents. In this environment, agents have to satisfy two different needs: **food** and **safety**.

These two needs were chosen because they represent different types of needs an agent/person-/bacteria could have. The food need is equivalent to the energy an agent has. Living costs energy, so the agents need to refill their energy or else they will cease to exist (Maslow, 1943). Food grows on the patches, and agents can choose to consume it. If an agent depletes a patch of food, there is a recuperation time before the food can start regrowing, which it then does exponentially.

Agents also need safety, the patches have safety, and an agent can be influenced by the patches and can influence the patches in return. A more detailed description of this is in the section 'Interaction' below. The safety need reflects a sense of safety an agent can have. Agents want to be in a place they feel safe, a home, and they find that in places where safety levels are high.

Entities, State Variables and Scales

The entities in the model are turtles and patches. Turtles are the NetLogo implementation of the agents in the model. Patches are the Netlogo implementation of the background or landscape the agents live on. There are two types of turtles: coping and co-creation turtles. Both types of turtles have the same state low-level variables. In the model, a coping turtle is shown as a black 'fish'-shaped object, and a co-creation turtle is shown as a white 'butterfly'-shaped object. Both can be seen in figure 1 on page 5.

Parameter	Purpose
food	The energy level of a turtle.
safety	The sense of safety a turtle has.
transfer	A counter to help determine whether a turtle will switch strategies.
age	The age of a turtle.

Table 1: Turtle-owned state parameters

The needs referred to in the 'Purpose' section can be seen in table 1. Also, under certain conditions (we'll come to those later) a turtle can change strategies from coping to co-creation or vice versa. This happens if they are in a certain state for a predetermined number of timesteps. The transfer counter keeps track of how long a turtle is in that state.

Parameter	Purpose
pfood	The available food on a patch.
psafety	The available safety on a patch.
pgrow	A counter for the number of time steps before food can regrow

Table 2: Patch-owned state parameters

A patch, or piece of background, also has low-level state parameters. It has its own food and safety levels. They are notated as **pfood** and **psafety**, the extra 'p' indicating that it is a patch-parameter. Patches also have a **pgrow** counter, which counts the number of time steps to be passed before the food can start regrowing after it has been depleted. Patches also have a colour, depicting how much food and safety a patch represents. If these values exceed a showing limit, it is shown in colour. For exact descriptions, see table 3. For an example of the setup colours, see figure 1.

Parameter	Purpose
green	Sufficient food and safety.
blue	Sufficient food, insufficient safety.
yellow	Sufficient safety, insufficient food.
red	Insufficient food and insufficient safety.

Table 3: Colouring of patches

Parameter	Value	Purpose
maxpfood	150	The maximum amount of food available on a patch.
maxpsafety	100	The maximum amount of safety available on a patch.
maxsafety	100	The maximum amount of safety a turtle can own.
maxtransfer	10	The number of time steps before a turtle can transfer strategies.
maxpgrow	10	The number of time steps before food can regrow on an empty patch.
minshowf	70	The minimum value of pfood necessary for showing its presence.
minshows	50	The minimum value of psafety necessary for showing its presence.
copingA	50	The number of coping agents in the model.
co-creationA	50	The number of co-creation agents in the model.
energy	1	The amount of energy/-food it costs to move.

Table 4: Global state parameters

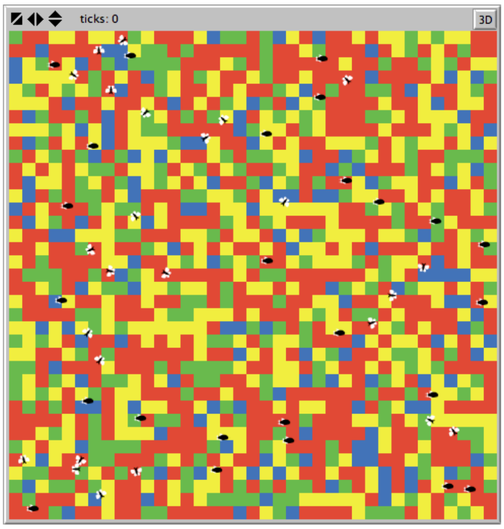

Figure 1: The world at setup

Most of the global values indicate the maximum value that specific properties of by the turtles or patches can reach.

There is a single population of agents, spread over the whole environment. That the turtles exhibit only coping and co-creation behaviour does not limit them in their position in the environment. Subopulations of coping and co-creation agents are followed separately to be able to compare them. This following is done by monitors on the **Interface** screen of the Netlogo application.

A full screenshot of the interface is visible in figure 2.

There are no exogenous drivers in the model. After setup, the reactions and interactions all come from within the model itself.

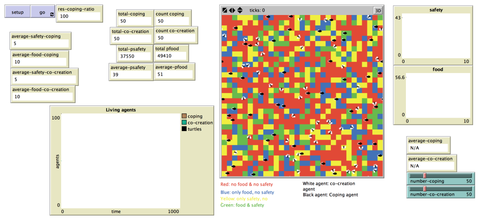

Figure 2: The full interface

Space in the model is represented by the patches in the background. The size of the background is 37 by 37 patches. Each patch measures 13 by 13 pixels. A turtle can be at any point on a patch. The number of patches in the background of the model can be altered.

Time steps are described as 'ticks' by NetLogo. Each time step, one tick passes. This model has short time horizons, every time step a new decision and evaluation are made, without regarding the action performed the previous time step. For the exact process of the above parameters, see the 'Process Overview and Scheduling' section below. The minimum values for each parameter is 0. The maximum values for the global parameters are set at the start of the model, and are visible in table 4.

Process Overview and Scheduling

Each tick, the turtles and patches are updated, and the number of coping and co-creation agents are counted.

While updating the turtles, their respective 'act'-functions are called. In these functions, the agents decide, depending on a combination of their own state, the state of the patch they're standing on, and their strategy, what they will do. So if they decide to eat the food on the patch, or if they do something with their own safety or with the safety of the patch they occupy. After this, the turtles move one step to a new spot in the world, and checks are performed to see if any turtles need to switch strategy, and if any turtle is ready to reproduce. Then, they are made a tick older.

In updating the patches, first the food grows a little, until it reaches its maximum value. How this happens is explained in the 'Purpose' section above. Then the safety diminishes a little to imitate the fading of a sense of safety if it is not reenforced. The process through which this is done is explained in the 'Interaction' section. After this, the patches are re-coloured, according to the colour scheme explained in table 3 on page 5.

A turtle is allowed to switch strategy if they manage to be in a certain state for more than **maxtransfer** ticks: if an agent is a co-creation agentand has low safety or low food for more than **maxtransfer** ticks, it will turn into a coping agent. On the other hand, if the agent is a coping agent, it can transfer into a co-creation agent if it has a high safety and high food level for the same number of ticks.

Turtles are ready to reproduce if they reach a certain 'good state', defined by both energy and safety levels exceeding 30. If they reach this, they have a 1 percent probability of actually reproducing. They then create a new turtle, in the same spot as the parent was standing. This turtle will start life in the same mode as their parent was, but with new food and safety levels, the same as an agent would have at the beginning of the run.

Design Concepts

Theoretical and Empirical Background

The theory underlying the design is the theory of the two modes of cognition (coping and co-creation) explained in the above 'Theory' section. Agents in the coping mode tend to choose the action which at that moment gives them the most need fulfillment. They optimise for themself. Co-creation agents think ahead and take actions that are the best actions for the environment to continue in a most stable manner. They optimise for themselves and for the environment.

These decision models align with the theory described by Andringa et al. (2015).

The data within the model is only available at the lowest aggretional level, at an individual level. This is because the two types of agents don't live as populations, but as individuals.

Individual Decision Making

The turtles make inividual decisions about whether to do something with the food and/or safety of the patch they are standing, after which they can move around. The coping agents strive to remian alive by fulfilling their needs, and the co-creation agents strive to co-create a world in which pressing needs occur less frequently. The agents decide based on their own state (how much food and safety they have) and on the state of the patch they are standing on. They adapt their behaviour to changing individual and environmental state variables.

Social norms play a role in as far as agents in coping or co-creation mode internalise that in their strategy. Spatial aspects are taken into account due to the fact that turtles can only access the information about the state variables of the patch they are standing on at that moment in time. Temporal aspects play no role. The model is episodic: the decisions made every tick are dependent only on the state of the world in that time step, and not on earlier time steps.

There is some uncertaincy left in the agents decision models. In some cases an action can only be performed if certain requirements are met, as well as that it only occurs occasionally. In the implementation a random number is generated, and if that number is beneath a set threshold, the action is executed. The margin and threshold differ in value depending on the situation. This occurs in maintaining safety levels and in reproduction, which are explained in more detail in the 'Interaction' and 'Process overview' sections respectively.

Learning

Individual learning is not included in the decision process. Collective learning is also not present in this model. For more on this, see the Discussion section.

Individual Sensing

Individuals sense their own state of being in the form of their own energy and safety levels. They also sense the state variables of the patch they are standing on. These variables are used to make their decisions. The sensing is always done correctly, there is no chance of loss of information. Individuals cannot perceive any state variables of other individuals or patches. The spatial scale of sensing is therefore limited to the exact position of the agents.

The sensing is implicit. An agent knows the information of the patch it is standing on, no other procedures need to be called. Because of this, there is no cost attached to acquiring this information.

Individual Prediction

The agents do not predict future conditions in this model.

Interaction

Interaction between turtles occurs in an indirect manner, via the 'background' of the model. All turtles can eat the food on the patches, and it will regrow, the turtles have no influence on that. The turtles have influence on the safety owned by the patches. A coping agent with a low own safety can have a negative influence on the safety level of the patch they are on, they can decrease the sense of safety on a patch by fractions depending on their own sense of safety. If they have a high safety value, they can also increase the safety level of the patch. However, as coping agents focus more on themselves than on their environment, this happens infrequently.

Co-creation agents are more focused on their environment, and they have greater knowledge how to influence the environment for the better. They have a stronger positive influence on their surroundings than coping agents.

Agents leave traces that can be perceived and built on by other agents. This works via the principle of stigmergy, which can be defined as the combination of two or more things that creates an effect which is greater than the sum of both separately. In this case it is the (different types of agents) interacting with the environment through safety levels simultaneously and that way interacting with each other via the environment.

Collectives

The agents do not gather into collectives. They are of two different types, but as they have no direct interaction with other turtles, there are no aggregations formed.

Heterogeneity

The agents are heterogeneous because there are two types of agents, the coping agents and the co-creation agents. They differ in the decision processes, but can switch between strategies as explained in the 'Process Overview and Scheduling' section above. The decision models that differ are all decisions that relate to fulfillment of needs and to interaction with the environment.

Stochasticity

The initialisation of the model is random at values that are evenly spread between the maximum and minimum levels of the different parameters. Turtles are spread over the entire model. The values the patches start with for food and safety are randomised as well. Another thing that is randomised are the processes that do not happen every time the entry requirements are met, but only a fraction of that time. Examples of this are moving around, reproduction, and the decision process allowing coping agents to have a positive influence on the environment.

Observation and Emergence

The key results and outputs that are collected are the average number of coping and co-creation agents present in the simultation for its duration, as well as the ratio thereof. The number of agents, divided in coping and co-creation agents, are monitored in a plot that is updated every tick, as can be seen in figure 3. Those allow us to see if there are sudden highs and lows in the number of agents. Also monitored are the level of food and safety available in the model.

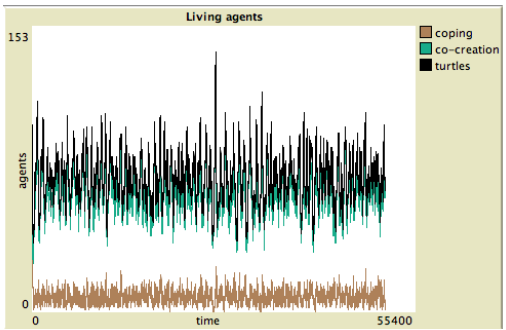

Figure 3: Plot of agents after 50.000 ticks with 50:50 agents

The main characteristic emerging from the model is that the ratio coping / co-creation agents remains dynamically stable throughout the whole simulation.

Details

Implementation Details

The model is implemented in NetLogo (Wilensky, 1999).

Initialisation

In the initialisation of the model some parameters are always set to the same value, derived from testing, others are initialised by taking a random value in a range. See the table 6 in the appendix for a full description and table 4 for a simpler version.

These random values differ per patch and per run of the simulation. The number of coping and co-creation agents can be differed, they are settings the user can alter on the 'interface' screen.

Initial values are chosen by testing a few times and seeing that these setting produce constant results.

Input

The model doesn't use any exogenous input after it has started running. It runs completely on the settings at initialisation.

Submodels

The model consists of 5 parts. A general part, a turtle part, a patch part, a reporter part and the interface.

The interface shows the user what is happening in the model. Buttons on the interface interact with the general part of the model. This general part starts the model at the assigned initialisation values (some of which can be altered in the interface). The general part keeps track of the running of the model. Every tick, the general part of the model will call on both the turtle and patch parts to update themselves.

The turtle and patch parts update themselves according to decision models explained above. Every time they are called on, they will for every turtle or patch update that agent, or act the act function connected to them. First all the turtles are updated, then all the patches. The order in which the different turtles and patches are updated within their respective update-functions differ. A turtle that was the first to be updated this tick will be most likely updated later in the next tick.

The reporter part keeps track of a number of variables with count functions or other implemented monitors. These results are then shown on the interface in monitor fields.

Method

Once the model was created, a number of parameters can be adjusted to approximate the behaviour of agents, such as humans or bacteria, in the real world. If any one of these parameters is changed, the outcome of the model can change qualitatively. However, it may also appear that this change has no effect on the outcome of the model.

The following parameters could be adjusted in per simulation:

- The difference in reaction to the fulfillment of the different needs between coping and co-creation agents
- The regrowth rate of the need-fulfilling parameters of the patches.
- The number of agents at the start of the simulation
- The ratio between coping and co-creation agents
- The level of needs where a coping agent can turn into a co-creation agents and vice-versa
- The maximum values of the food and safety
- The speed with which agents can reproduce

The difference in reaction to fulfillment of needs is explained in the section regarding 'Individual Decision Making'. This is a most critical part of the model, because the difference in reaction is synonymous with the definition of the mode.

Without this difference in reaction, there would not be a model to test.

The regrowth parameters: as stated in the section regarding parameters, the food has a standard exponential regrowth rate until it reaches a maximum value. If a patch has been completely depleted of food, nothing will grow there for the next 10 ticks. Both the rate with which it grows and the number of ticks nothing can grow can be altered, but for this experiment, these values have been kept constant. The number of ticks in which there is no growth is defined in the parameter **maxpgrow** and the **pgrow** parameter for each patch keeps track of how long the patch should 'wait' before restarting growth.

The number of agents in the environment, and the ratio between coping and co-creation agents could have a great effect on the stability in the system. Variations in these values are discussed in the 'Results' section.

It is possible for an agent to transfer from a coping agent into a co-creation agent and vice versa. A coping agent can turn into a co-creation agent if they managed to fulfill their needs continuously, which would indicate better understanding of the environment. Similarly, a co-creating agent can switch to a coping strategy if they leave their needs unfulfilled, indicating less understanding. To implement this, we set boundaries at a certain value for both parameters. These transfer rates are set on initialisation and are defined as above 30 energy and 20 safety to become co-creation and below 10 energy and 5 safety to become coping. If an agent passed those boundaries for more than 10 ticks in a row, they change into an agent of the other type. As with the regrowth parameters, these parameters are what happens to work for the system in its current implementation, but are also changeable. These parameters are mentioned in table 7 in the appendix.

If an agent doesn't manage to satisfy its needs sufficiently, it dies. If the value for either food or safety get below 0, the agent dies. The maximum amount of food or safety an agent can have is determined at the beginning of a run of the simulation. These values can be found in table 6 in the appendix. These settings are also in table 7 in the appendix.

To simulate an environment where agents live and thrive and die and maintain a balanced system, agents also need to be able to reproduce, otherwise the population will only decrease. To facilitate this, we have created a function that checks whether the circumstances are favourable for the agent to create offspring.

Many of the above specified parameters could be varied, but we found that these parameters gave a suitable basis to experiment on to create a dynamically stable environment with.

Results

As can be seen in figure 5 (at t = 50.000) and figure 4 (at t = 2000) the agents are still spread randomly over the world. Recall that the co-creation agents are white 'butterflies' and the coping agents are black 'fish'.

To test the stability of the model, we tested the following initial population distribution: a 1:1 ratio, a 2:1 and a 1:2 ratio and a 0:X and X:0 ratio. The 1:1 ratio we tested with the values 50:50, 25:25, 5:5 and 200:200, to see if the number of agents present at the beginning of the simulation had any influence on the average number of agents. See table 5 below for details. In the first column is the number of agents started with, with a format of **co-creation : coping**. In the second column is the number of agents after 50.000 ticks, again formatted as **co-creation : coping**.

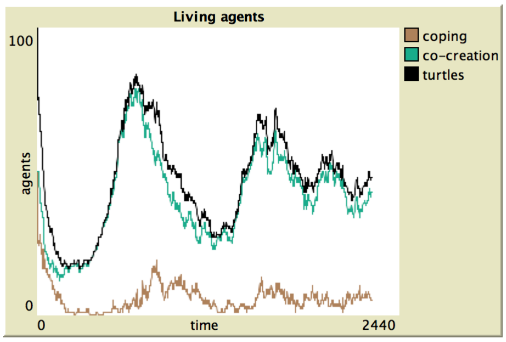

Figure 4: The world after 2000 ticks and 50:50 agents

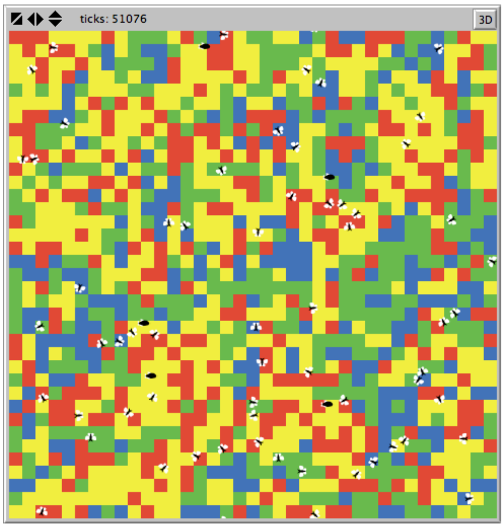

Figure 5: The world after 50.000 ticks and 50:50 agents

Population size at start	Average ratio at t = 50.000
50 : 50	62.2 : 7.8
100 : 50	62.7 : 7.8
50 : 100	61.4 : 7.9
0 : 50	61.5 : 7.6
50 : 0	62.4 : 7.9
25 : 25	62.1 : 7.7
5 : 5	60.6 : 7.5
200 : 200	61.9 : 7.8

Table 5: Ratio agents

The total interface at 50.000 ticksis in figure 6. Larger version can be found in the appendix.

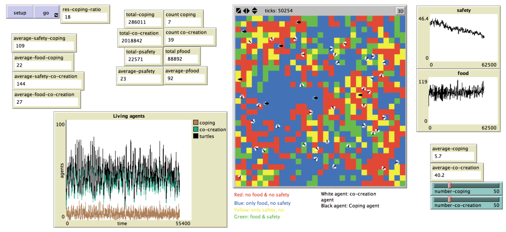

Figure 6: The full interface at t = 50000

We tested each setting thrice, the numbers shown above are the average of the three results. The ratio is approximately 8:1 co-creation vs coping agents for all of the above conditions.

We also tested a setting with 51 by 51 patches, in stead of 37 by 37. We ran the model with 50 co-creatio agents and 50 coping agents. This setup was also dynamically stable, with a ratio of 118.5 co-creastion by 14.8 coping. This is also a 8:1 co-creation vs coping agents ratio.

Discussion

The results show that there is dynamically stable environment with the current model. It shows that a model focussed on two needs can produce a dynamically stable equilibrium, under multiple conditions. It apears that the number of agents at start or the size of the environment don't matter, the model will always converge to a 8:1 co-creation to coping ratio given the current parameter set. As the model represents the theory of core cognition proposed by Andringa et al. (2015), we can say that these results would add to the plausibility of that theory.

However, the model is not complete, as it only takes two different needs into account. A model could be made almost as complex as a real world situation, or as simple as this one. We could add extra needs, that would make it more difficult for agents to balance them, or constraints could be placed that make it more difficult to fulfill these needs.

The most important part to improve on in our opinion is the implementation of learning and understanding. In the current model, the co-creation agents interact in a more positive manner with the environment because we implemented these interactions. What would be more realistic (and therefore better to confirm the core cognition theory) would be to implement a manner of learning, that agents can gradually learn to do better or worse, or that agents even within the same mode can learn different strategies.

As the model does not specify that the agents have to be human-like, the model is moderately scalable. It could be applied to different levels of society in which agents function. This model could apply to both bacteria and humans, just as asserted in Andringa et al. (2015).

The current settings keep the model stable, and it doesn't vary with population or age size, but it is unsure what would happen if a number of processes would be changed. Especially the processes that are determined by the environment, and don't react to the rest of everything happening around them, such as the growth of food. Also, changing reproduction rate or the amount of safety shared could change a lot. The different aspects of a model need to balance each other. For example, a high reproduction rate means a lot of agents, which will quickly die out because of lack of food. This too can be dynamically stable. However, the amplitude of the number of agents in the graph in figure 5 would be much higher. This also might be something for future exploration.

Conclusion

Thus, we can conclude that it is possible that agents defined on a spectrum from coping to co-creation can exist in dynamic stable equilibria with their environment. It appears that as long as there are co-creation agents in the simulation the number of agents per type will converge to the same average. This is roughly 60 agents alive at any one time for the co-creation agents, and 10-15 for the coping agents. This is a 8:1 ratio. If the set parameters are changed, or if the implementation of the strategies is altered, the result will be different, though the model will stabilise at the same 8:1 ratio. This model is too low-level to be able to completely cover the complexity of human or even bacterial nature (Andringa et al., 2015; Maslow, 1943), so further expansion of the model will be necessary to be able to attach more worth to the conclusions. However, the results indicate that a stable and self-maintaining system can be created using solely agents defined by one of the two contrasting modes of cognition. This would in turn give more support to the theory defined by Andringa et al..

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Appendix

State Variable Tables

Parameter	Value
Global:	
copingA	50
co-creationA	50
maxpfood	150
maxpsafety	100
maxsafety	100
maxtransfer	10
maxpgrow	10
minshowf	70
minshows	50
energy	1
Patch:	
pfood	random between 0 and 100.
psafety	random between 0 and 80
pgrow	0
Turtle:	
food	10
safety	5
transfer	0
age	0

Table 6: Initialisation settings

Parameter	Value
Death	Food or Saftey below 0
Turn co-creating	Food above 30 and Safety above 20
Turn coping	Food below 10 and Safety below 5

Table 7: Change Settings

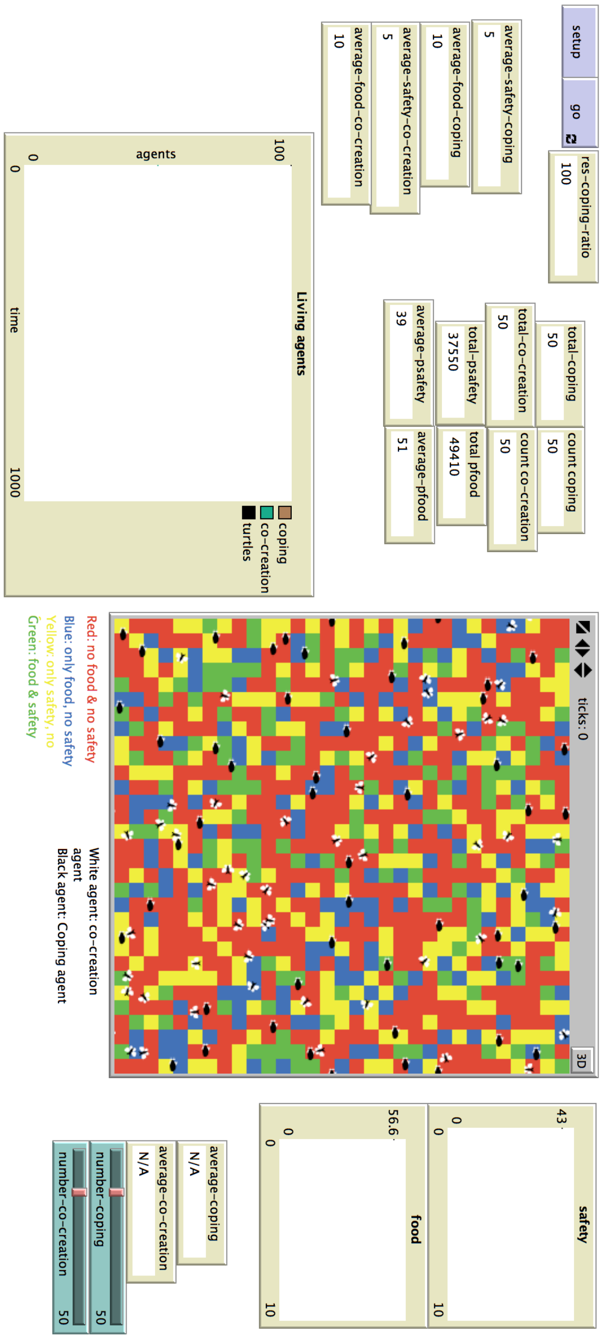

Figure 7: The full interface