Intermediate selection pressure bring in the emergence of altruism and common words

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Abstract. Many animals show altruistic behavior by using signals, such as alarm calls. However, few study have discussed the coevolution of altruistic behavior and common words among agents, although many studies have discussed how altruism have evolved. In this study we performed simulation experiments in order to explore the condition of the emergence of altruistic behavior with common words between agents who pursue their own profit. The result suggests that some kinds of altruism and common words are emerged under intermediate selection pressure and altruism can be a dominant strategy for agents under such a condition. Our results also suggest that the dynamics of resources would be one of important keys to the understanding of the emergence of altruism.

1 Introduction

According to Richard Dawkins (1989), as a result of natural selection, selfish genes that are capable of reproducing themselves accurately and efficiently have survived [1]. On the other hand, individuals that are vehicles of the genes seem to show not only selfish behavior but also altruistic behavior, and to have developed common vocabularies not only to profit together but also to bring benefit to others by informing the existence of foods and hazards. Why do individuals that should take selfish behavior for the preservation of their genes have such common vocabularies and take altruistic behavior?

W. D. Hamilton proposed the idea that the basic unit for the evolution is a fragment of a gene and proposed the idea of kin selection [2, 3]. On the other hand, D. S. Wilson stated between-group selection is the basic key of the evolution of altruism and proposed the multi-level selection [4]. Even in recent years there are many arguments between these ideas [5, 6]. Then, is the concept of between-group selection necessary to the emergence of altruistic behavior?

The mechanism of the emergence of altruistic behaviors has been discussed without considering communication ability explicitly in most studies. However, a kind of communication would be necessary for cooperative behaviors. Many animals behave altruistic by using signals, for examples vervet monkeys warn the existence of predators by alarm call. Therefore, the emergence of signals commonly used among agents would be an important factor for the emergence of altruistic behavior. Some simulation studies have been done to discuss the evolution of common words [7, 8]. However, in most of the studies a word (or a symbol) to express an object is assumed to be acquired among agents by a mutual mimicry of words for an object through common experiences, which implies that a learning mechanism of common words is prepared a priori in these studies. However, the emergence of common words should be explained from a view point of natural selection.

We have examined the condition of the emergence of cooperative behavior and common words among agents who pursue their own profit by computer simulations [9]. The simulation results indicated that the words which point out an object and a cooperative relation emerge when agents can obtain more profit by the cooperation. However, neither a word nor a cooperative relation for non-profitable objects such as a predator was emerged. In the previous study, the duplication and death of agents were determined by a comparative assessment, that is, agents who obtained higher score than others could survive. It would be a reason why altruistic behavior did not emerge, because if one informs others hazard, its own relative domination falls. Then, does the factor of absolute assessment for selection bring altruistic behavior among agents?

In this paper we report a result of simulation experiments to consider the mechanism of the coevolution of altruistic behavior and common words.

2 Simulation method

We prepared a virtual field on a computer where foods and predators are put on, and agents move around. Each virtual agent determines its action, i.e. the direction of movement and the word to emit, from the state of the current cell and a word from a neighbor. The input-output relation is improved through evolutional process. We examined the condition of the emergence of common words to express objects and cooperation among agents. Here we call signals which agents transmit to others as words. Details of the simulation method are as follows.

2.1 Virtual field

We prepared a two dimensional torus composed of 10×10 cells as a virtual field. Foods and predators which are objects giving positive and negative rewards for agents, respectively, are put on each cell with the probability of 0.5% and 20%, respectively, as an initial condition, and added to empty cells with the probability of 1% and 0.5%, respectively, for every simulation step. In order to prevent extinction of agents, the appearance probability of foods was set higher than that of predator. We also have confirmed that the following results do not change qualitatively by the change of these values. If an agent stays at a cell with a predator for three consecutive steps, the predator disappears. If an agent stays five steps at a cell with a food, the food disappears.

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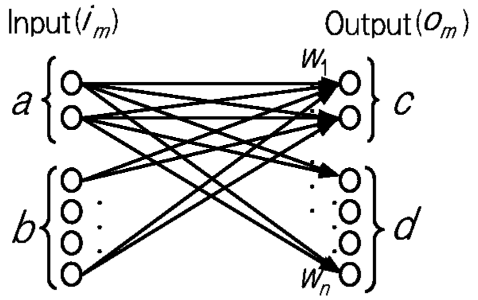

Figure 1. The input-output relation of an agent. The output shows the direction of a movement in the next step (signal c) and a word to speak to neighbors (signal d) are determined by the weighted sum of the elements of input signal. The input signal shows the information on the current position (signal a), and the word transmitted from a neighbor (signal b). For the simplification of data analysis, no connection from the received word (signal b) to the word to emit (signal d).

2.2 Agents

In each simulation step, each agent decides its movement and a word to speak to neighbors from input signals. The input signal involves two kinds of information. One is a 2-bit binary and shows the information of the current position (signal a in Fig.1) : the existence of a food (01), a predator (10), or nothing (00). The other is a 4-bit binary which shows a word transmitted from another agent in its eight neighboring cells (signal b in Fig.1) for simplicity. When an agent receives more than one word at the same time, the agent chooses one at random. When no word is received or no agent exists in neighboring cells, the signal was set as 0000. The output signal is determined by the weighted sum of the elements of the input signal, where the weights (w_i in Fig.1) take binary values. When the element of the output signal takes a non-binary value, it is replaced by the remainder of the value divided by 2. The output signal shows a word to emit (signal d in Fig.1) and the action taken at the next step (signal c in Fig.1) : moving to the cell where the received word was emitted (01), moving to a cell where no word was emitted (10), staying at the current cell (11), or moving to its nine neighboring cells including the current position, randomly (00). In the following sentences, we define 'the approaching action' as 'moving to the cell where the received word was emitted' and 'the avoiding action' as 'moving to a cell where no word was emitted or staying at the current cell'. As an initial condition the number of agents on the virtual field was set as 20, and the weights were set randomly. The weight value of each agent is fixed in its life time.

2.3 Survival conditions and Learning method

Each agent consumes 0.1 point at every simulation step as metabolic cost, and 0.5 points when they emit words. If an agent stays in a cell with a food, it obtains a reward of 1 point, and if an agent is in a cell with a predator, it obtains a negative reward of y points, where the reward was changed as $y = -1, -2, \cdots, -10$ for each simulation condition.

The agent whose point reaches 100 points makes an offspring. The weight values which determine the input-output relation are copied from the parent to the offspring, but copy error occurs by a given mutation rate. The agent whose point becomes below a given threshold x dies and the threshold is changed as $x = -30, -60, -90, \cdots, -900$ for each simulation condition, where the highest threshold $x = -30$ means the most severe environment for agents to survive. Therefore, the threshold can be regarded as a kind of selection pressure for the survival of agents. One simulation involves 100,000 steps and 1,000 simulations were performed for each reward condition y and threshold x from random initial states and random weight values. The obtained results, such as the number of agents which take a specific action, were averaged over a simulation steps and were normalized by the average of the number of agents in the simulation, and then averaged again over 1000 simulations for each simulation condition of x and y.

3 Results and discussions

In the following sentences, we define 'a word expressing a food (or a predator)' as 'a word emitted by an agent in a cell with a food (or a predator)' and 'approaching (or avoiding) action for "the word food" (or "the word predator")' as 'the action of approaching (or avoiding) the cell where a word expressing a food (or a predator) is emitted'.

3.1 Coevolution of altruistic behavior and common words

Figure 2, 3, 4 and 5 show the maximum duration steps in which agents successively choose an action, approaching or avoiding, when agents receive words expressing a food and a predator, respectively, against the threshold x of death condition and reward y of a predator. Figure 2 and 5 show that approaching action for "the word predator" and avoiding action for "the word food" were not chosen by agents. In other words, agents who chose such action were weeded out.

Figure 3 and 4 show that maximum duration of the avoiding action for "the word predator" and the approaching action for "the word food" is observed in the area which gives intermediate selection pressure, i.e. along the diagonal line from the upper right to the lower, respectively. In the upper left and lower right areas of Fig. 3 and 4 agents do not take the avoiding action for "the word predator" and the approaching action for "the word food" over a long duration, and agents tend to emit no words. Because in the upper left area the threshold x is low and the damage y by a predator is small, which makes agents scarcely die, therefore, agents do not need to speak for searching foods. In the lower right area threshold x is high and damage y is large, which would prevent agents to lose points by emitting words. However, except such areas the avoiding action for "the word predator" stably emerged in almost every environment (Fig. 3). These results suggest that the cooperative behavior to inform the existence of the foods and predators stably emerges under intermediate selection pressure with absolute evaluation in spite that such altruistic behavior can decrease the relative fitness of doers.

Figure 6 and 7 are the example of transition of words expressing a food and a predator, respectively, when the reward of predator is -7 points and dead threshold is -150 points. In each figure, the solid line shows the number of agents which did not emit words for a food. However, it is not invisible in the figures because the line is on the horizontal axis. The other lines show the number of agents which emitted certain word to express an object, respectively. These figures show that common words expressing a food and a predator emerged and stably observed, although, transition word expressing a predator was sometimes observed as in Fig. 7. Such emergence of common words was observed under intermediate selection pressure where both types of cooperative behaviors, avoiding predators and approaching foods by informing the existence each other, were

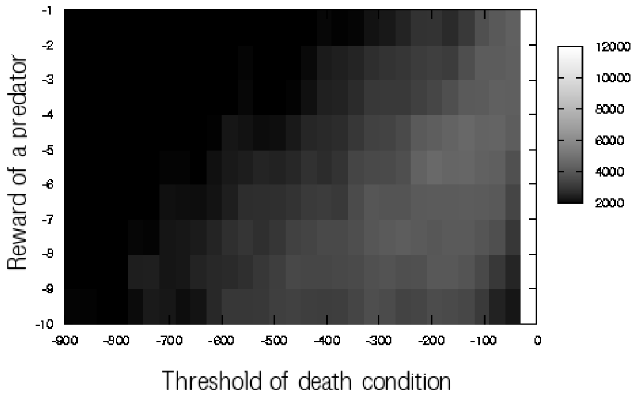

Figure 2. The average of maximum duration of the approaching action for "the word predator". The abscissa and ordinate are the threshold x of death condition and the reward condition y, respectively. The average was taken over 1000 simulations for each condition.

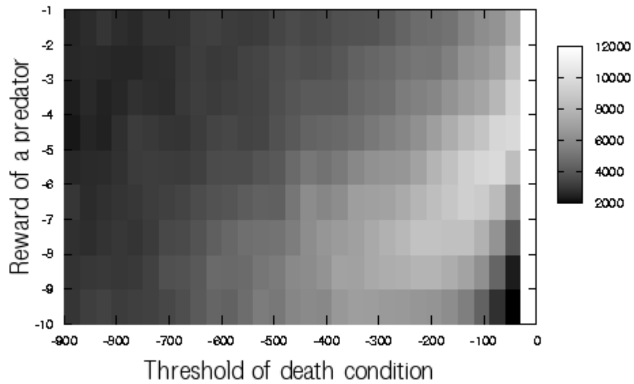

Figure 4. The average of maximum duration of the approaching action for "the word food". The abscissa and ordinate are the same as Fig. 2.

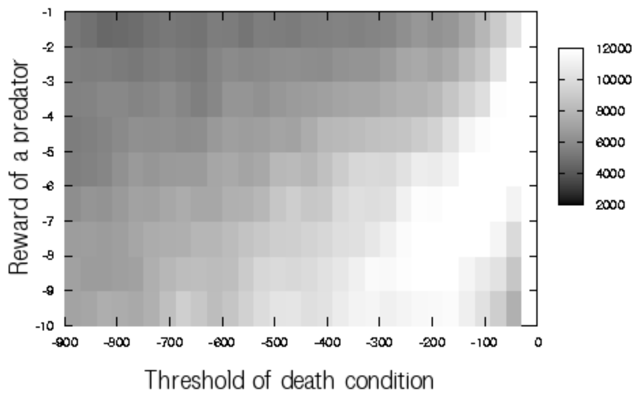

Figure 3. The average of maximum duration of the avoiding action for "the word predator". The abscissa and ordinate are the same as Fig. 2.

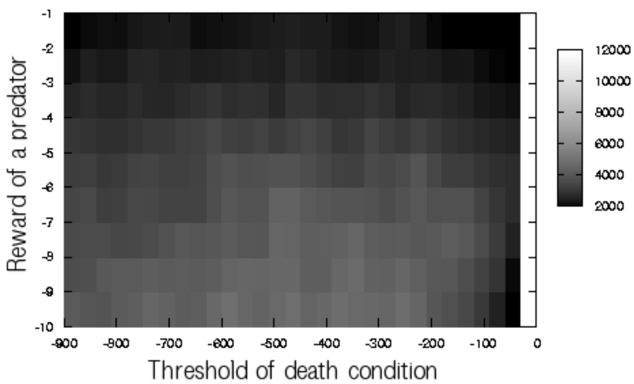

Figure 5. The average of maximum duration of the avoiding action for "the word food". The abscissa and ordinate are the same as Fig. 2.

emerged. Figure 8 and 9 show the action chosen by agents which received "the word food" and "the word predator", respectively. The solid lines show the ratios of the action "going to the cell where words expressing a food" and "going to the cell where words expressing a predator", respectively. The dashed lines show ratios of the actions "avoiding the cell where words expressing a food" and "avoiding the cell where words expressing a predator", respectively. It is clear that most agents go to the cell where words expressing a food is emitted (Fig. 8) and avoid the cells where words expressing a predator is emitted (Fig. 9). Therefore, both of common words and altruistic behaviors emerged under the intermediate selection pressure. However, in other area, i.e. , in the upper left area or in the lower right area, agents tend to emit no words expressing either a food or a predator. For example, Fig. 10 and 11 show an example of transition of words expressing a food and a predator, respectively under the condition that the reward of predator y is -1 point and the death threshold x is -900 points. The meaning of the lines is the same as those in Fig. 6 and 7. These graphs show that most agents emit no words for objects. Figure 12 and 13 show the action chosen by agents which received "the word food" and "the word predator", respectively. No cooperative behaviors emerged in these conditions (Fig. 12 and 13). Therefore, the coevolution of altruistic behavior and common words was confirmed only under the intermediate selection pressure.

3.2 Effect of communication

We examined how the communication affects the number of agents and objects. Figure 14, 15, and 16 show the mean number of agents, foods and predators, respectively, against the threshold x of death condition and reward y of a predator. Figure 17, 18, and 19 show the same ones as Fig. 14, 15, and 16, respectively, except that the simulation was done under the condition that agent always emit no word.

Figure 14 and Fig. 17 show that the number of agents who have communication ability is greater than the number of agents who do

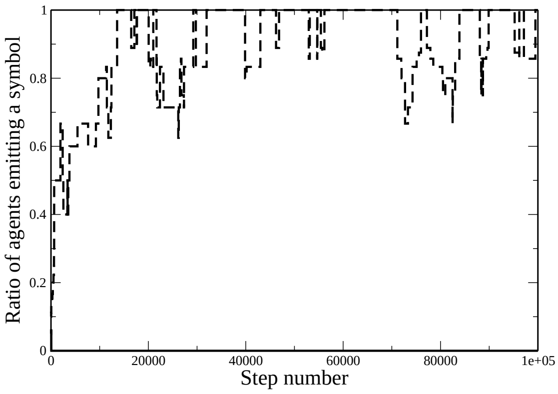

Figure 6. A typical pattern of transition of words expressing a food. The abscissa is step number. The ordinate is the ratio of agents emitting each symbols to the number of agents. The solid line shows the number of agents which did not emit words for a food. The dashed line shows the number of agents which emitted '1000' to express a food. In this simulation reward of predator is -7 points and dead threshold is -150 points.

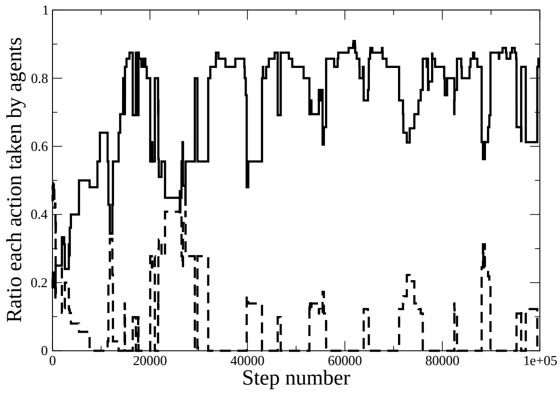

Figure 8. The ratio of each action chosen by agents which received a word expressing a food. The abscissa is step number. The ordinate is the ratio of each action taken by agents. The solid line shows the ratio of the action "going to the cell where words expressing a food". The dashed line shows ratio of the actions "avoiding the cell where words expressing a food". The simulation condition is the same as Fig. 6.

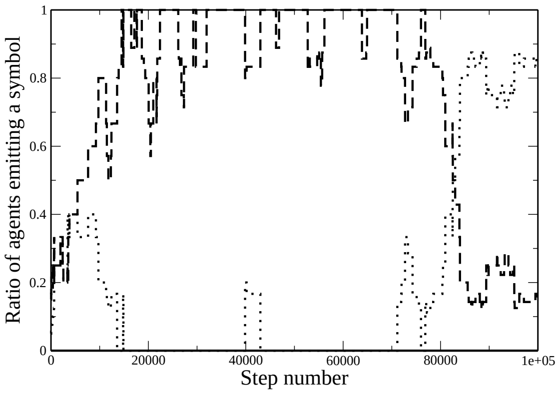

Figure 7. A typical pattern of transition of words expressing a predator. The abscissa and ordinate are the same as Fig. 6. The solid line shows the number of agents which did not emit words for a predator. The dashed and dotted line shows the number of agents which emitted '1101' to express a predator and '1110', respectively. The simulation condition is the same as Fig. 6.

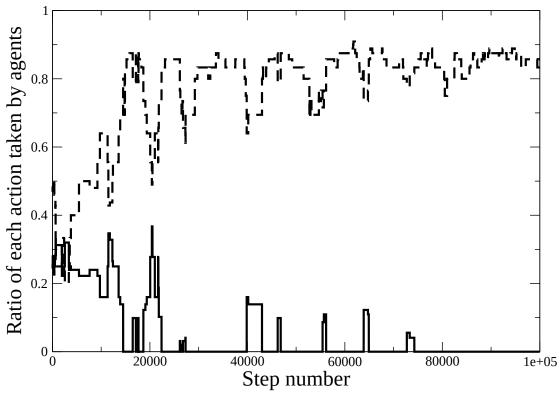

Figure 9. The ratio of each action chosen by agents which received a word expressing a predator. The abscissa and ordinate are the same as Fig. 8. The solid line shows the ratio of the action "going to the cell where words expressing a predator". The dashed line shows ratio of the actions "avoiding the cell where words expressing a predator". The simulation condition is the same as Fig. 6.

not have one. Interestingly, in spite of the change of the number of agents, the number of objects shows little change by the communication (Fig. 15, 16, 18, and 19). These results show that some kinds of cooperation can exploit the dynamics of objects and increase the carrying capability of agents.

4 Conclusion

In this study we examined the condition under which altruistic behavior and common words emerge among agents that pursue their own profit. The results suggest that altruistic behaviors such that informing the existence of objects to others and the common word easily emerges among agents under the selection by absolute evaluation in spite that telling the existence of predator to others does not bring benefit to the speaker but might decrease its relative dominance to others.

D. S. Wilson said "Altruism decreases the relative fitness of the altruist within the group. However, groups of altruists are more fit than groups of nonaltruists" [4]. If there are only limited number of resources in environment or the carrying capacity of environment is a constant, altruism, such as informing the existence of the resources to others, would decrease the relative fitness of the altruist as Wilson suggested. However, when the amount of resources changes according to its dynamics, some kinds of altruism which increase the carrying capacity by exploiting the dynamics emerges without between group selection as shown in our results showed. Although some studies based on multilevel selection discussed altruism under the constant carrying capability and some studies such as kin selection discussed altruism without considering carrying capability, our result indicate that the capability depends on the type of cooperation and the effect of altruism on the capacity would be one of important keys to understand altruism. In other word, we should pay more attention to the effect of cooperation on the dynamics of agents and environment to discuss altruism.

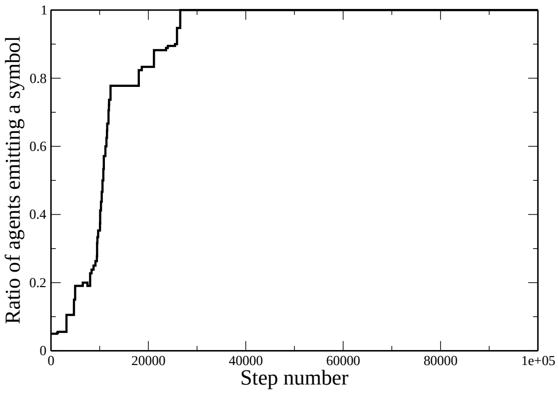

Figure 10. The example of transition of words expressing a food. The abscissa and ordinate are the same as Fig. 6. The solid line shows the number of agents which did not emit words for a food. In this simulation reward of predator is -1 points and death threshold is -900 points.

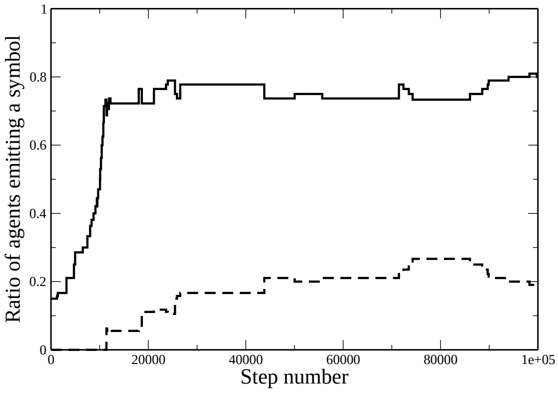

Figure 11. A typical pattern of transition of words expressing a predator. The abscissa and ordinate are the same as Fig. 6. The solid line shows the number of agents which did not emit words for a predator. The dashed line shows the number of agents which emitted '1101' to express a predator. The simulation condition is the same as Fig. 10.

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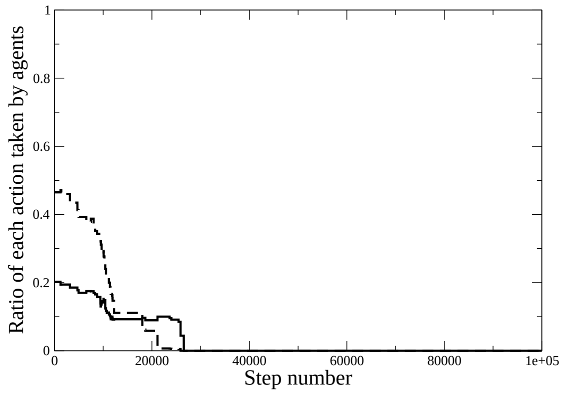

Figure 12. The ratio of each action chosen by agents which received a word expressing a food. The abscissa, ordinate and these lines are the same as Fig. 8. The simulation condition is the same as Fig. 10.

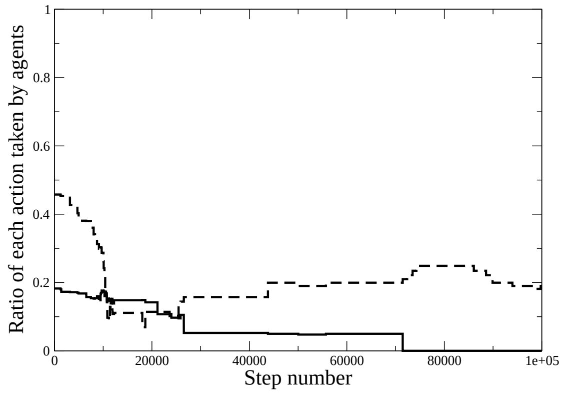

Figure 13. The ratio of each action chosen by agents which received a word expressing a predator. The abscissa, ordinate and these lines are the same as Fig. 9. The simulation condition is the same as Fig. 10.

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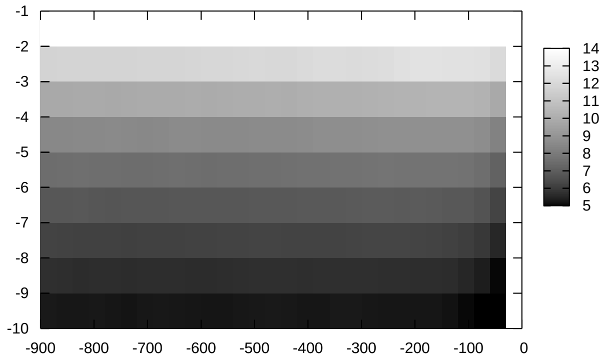

Figure 14. The average of number of agents. The abscissa and ordinate are the same as Fig. 2.

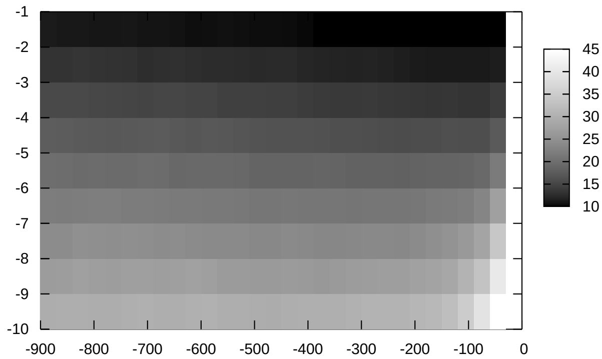

Figure 15. The average of number of foods. The abscissa and ordinate are the same as Fig. 2.

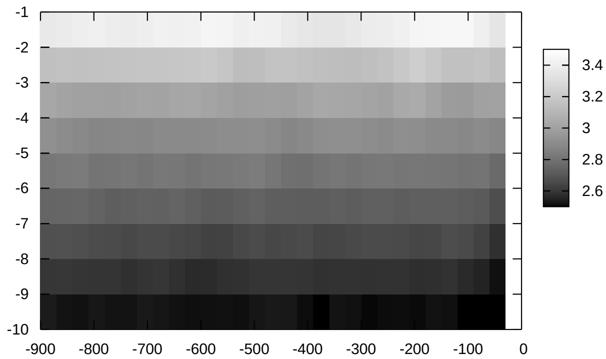

Figure 16. The average of number of predators. The abscissa and ordinate are the same as Fig. 2.

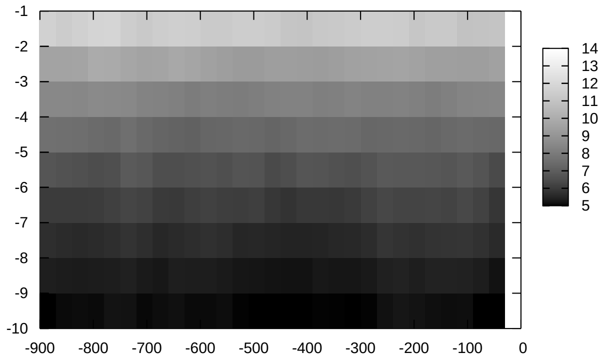

Figure 17. The average of number of agents on condition that agents do not have communication ability. The abscissa and ordinate are the same as Fig. 2.

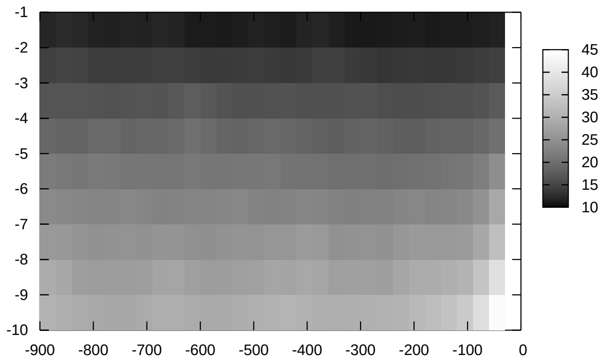

Figure 18. The average of number of foods on condition that agents do not have communication ability. The abscissa and ordinate are the same as Fig. 2.

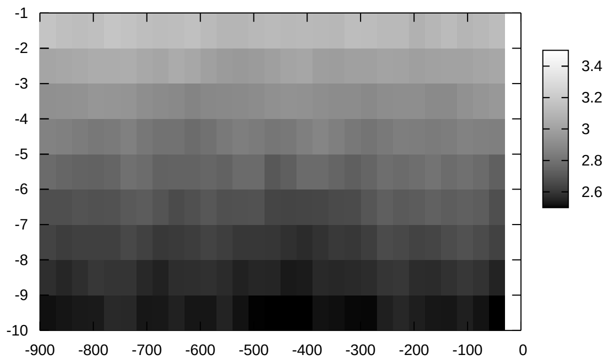

Figure 19. The average of number of predators on condition that agents do not have communication ability. The abscissa and ordinate are the same as Fig. 2.