Model Structure of Agent-Based Artificial System for Reproducing Bullying Phenomenon

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Introduction

Bullying refers to negative actions perpetrated by and toward one or more individuals that are conducted repeatedly over a period. The negative actions may include harassing, mobbing, offending, and socially excluding.

Although bullying is a crucial phenomenon not only in school, but also in the firm, it is continuing to occur and no effective countermeasures have been established.

One reason for that seems to be that the underlying mechanism of bullying is not well understood, probably because, the research approaches of the previous studies are limited to the interviews or questionnaire mostly with the victim.

On the other hand, we should note that agent-based modeling (ABM) is an effective approach for studying the mechanism of the emergence of social phenomena.

The most essential feature of ABM is that it is a bottom-up modeling method. Due to this feature, I believe the mechanism of social phenomenon can be elucidated using ABM based on the following concept.

< **The basic concept of ABM to elucidate the mechanism of social phenomenon**>

1. Any macro phenomenon in the real world is caused as a result of agents' actions and their interaction.
2. In principle, using ABM, we can construct an artificial system on a computer in which macro phenomenon emerges in the same mechanism as in the real system.
3. However, in order for this emergence of macro phenomenon to be realized in the model, the system structure of the model must be the same as that in the real system, which I defined as **a set of the categories of agents, their behavioral rules and relevant attributes variables.**
4. The system structure of the model that is required to reproduce the phenomenon can be elucidated by a series of computer experiment in which one factor is changed at a time with other factors being kept unchanged.
5. Then, considering the reason why such system structure is indispensable, we can get a better understanding about the causal mechanism of the macrophenomenon.

The macrophenomenon associated with bullying is characterized by two features.

1. The emergence of bullies as the perpetrator, the bullied as the victim, and a third party which consists of bystanders, reinforcers for the bullies and defender of the victim.
2. The persistent and repeated attacks by the perpetrator focusing on the victim and both of them are particular agents.

Some researchers have used ABM to study the bullying phenomenon. An example is the article presented by Maeda et al. who modeled the tuning and excluding actions and reproduced the emergence of a group as well as a solo agent.

However, few studies so far have succeeded in reproducing the bullying, probably because they have not well tried to analyze the system structure of the model which is considered indispensable to reproduce the phenomenon.

This study tried to show an evidence of the existence of indispensable system structure to reproduce the phenomenon, with the knowledge of which we can get a better understanding about the mechanism of the phenomenon.
Based on the findings, we proposed the underlying mechanism of bullying and the countermeasures that are considered effective.

The model

1. Each agent has a value vector, each component of which corresponds to traits in the real world, such as skills, preferences, behavioral patterns, etc.

$$V_i = \{v_{i,1}, v_{i,2}, v_{i,3}, \ldots\ldots\ldots\ldots, v_{i,M}\} : A\,set\,of\,\,value-related\,\,\,factors\,of\,\,agent\,i$$

$$v_{i,k} = 1\,(when\,\,selected)$$

$$= 0\,(when\,\,not\,\,selected)$$

The total number of selected values of agent i ranges between the upper and lower limit.

$$m_i = \sum_{k=1}^{M} v_{i,k}\,, \qquad m_{\min} \le m_i \le m_{\max}$$

2. A pair consisting of an active agent and an objective agent is selected at random, and the active agent performs either tuning action, excluding action, or doing nothing, depending on the criteria for the type of action, which includes action probability as a critical variable defined below.

$$p(act, obj) = c(act, obj) / m_{act}$$

$$where, \quad c(act, obj) = \sum_{k=1}^{M} v_{act,k} \bullet v_{obj,k} : Number\,\,of\,\,\,shared\,\,\,values$$

$$act: \quad active\,agent\,\,who\,performs\,the\,\,action, \qquad obj: the\,\,agent\,\,who\,is\,the\,object\,\,of\,\,\,the\,\,action$$

2.1 Tuning action

is the type of action that modifies the set of selected values of active agent to make it closer to that of the objective agent, defined below.

The active agent randomly selects one of the k values characterized as $v_{act,k}=0, v_{obj,k}=1$ and changes its own value to $v_{act,k}=1$
If this procedure makes the total number of values m_{act} greater than the upper limit $m_{\max}$ the active agent additionally selects another value p at random from the set of values characterized as $v_{act,p}=1, v_{obj,p}=0$ and changes the value to $v_{act,p}=0$.

2.2 Excluding action

is the type of action that modifies the set of selected values of objective agent to make it more different from that of the active agent, defined below.

The active agent randomly selects one of the k^{th} values characterized as $v_{act,k}=1, v_{obj,k}=1$ and changes the value of objective agent to $v_{obj,k}=0$, when $m_{obj}>m_{\min}$

2.3 Criteria for active agent to perform ether tuning, or excluding, or doing nothing. (Changed as the experimental condition)

Tuning action

The tuning action is conducted when below-condition is fulfilled.

$$p(act, obj) > g_{act}$$

$$where\ g_{act} : agent's\ threshold\ of\ tuning\ action$$

Experimental condition
EC4,EC5,EC6,EC7

or

$$p(act, obj) > \delta$$

$$where\ \delta : uniform\ random\ number\ in\ the\ range\ [0,1]$$

$$computed\ at\ each\ step$$

EC1,EC2,EC3

Excluding action

The excluding action is conducted when below-condition is fulfilled.

$$p(act,obj) < e_{act}\ \ and\ \ m_{act} > m_{obj}\quad where\ e_{act} : agent's\ threshold\ of\ excluding\ action\ \ (EC6, EC7)$$

or

$$m_{act} > m_{obj} \qquad (EC3, EC4)$$

or

$$p(act,obj) < e_{act} \quad (EC5)$$

or

$$c'(act,obj) - c(act,obj) > 1 \qquad (EC2,\ Maeda's\ \text{model})$$

$$where\ c(act,obj) : Number\ of\ shared\ values\ in\ the\ current\ step$$

$$c'(act,obj) : Number\ of\ shared\ values\ in\ the\ previous\ step$$

2.4 Reactive action against exclusion(EC7)

Effect of reactive action against the exclusion is tested, expecting to reproduce the second feature of bullying phenomenon.

In this model, characteristic random number in the range [0,1] is assigned to each agent.
Depending on this number, an agent that has just been excluded by the objective agent performs one of the three choices, namely an excluding action, a tuning action, or doing nothing toward the objective agent.

This action is conducted in addition to the shared-value-dependent tuning or excluding actions.

3. Procedure of calculation

Repeating the agent's action for all of the agents makes up one step of the calculation. This step is repeated until the equilibrium state has been attained.

During the repeated steps, the pattern of the selected values of each agent may change.

- Tuning actions increase the number of selected values in some agents, leading to the emergence of a group in which the members have the same set of values.
- Excluding actions decrease the number of selected values, leading to the emergence of solo agents who do not share any value with other agents.

4. Definition of the types of agents in the model.

- *The perpetrator is the agent who excludes others the most.*
- *The victim is the agent who is excluded by others the most.*
- *Third party is the other persons consisting of the bystanders who are rarely excluded and rarely excludes others, and reinforcers of the perpetrator and defender of the victim are differentiated depending on the number of exclusion and the number of times of being excluded.*

Table 1 Calculation conditions.

		Model with agent-specific rules				Model without agent-specific rules		
		Model with the structure of base model and the reaction against exclusion	Model with agent's threshold of tuning and exclusion(Base model)	Model with agent's threshold of tuning, where exclusion condition is changed		Model with revised rule of exclusion	Model presented by Maeda	Model with tuning only
Name of experimental condition		EC7	EC6	EC5	EC4	EC3	EC2	EC1
Behavioral rules of agent	Tuning	$p(act,obj)>g_{act}$	$p(act,obj)>g_{act}$	$p(act,obj)>g_{act}$	$p(act,obj)>g_{act}$	$p(act,obj)>\delta$	$p(act,obj)>\delta$	$p(act,obj)>\delta$
	Exclusion	$p(act,obj)<e_{act}$, $m(act)m(obj)$	$p(act,obj)<e_{act}$, $m(act)m(obj)$	$p(act,obj)<e_{act}$	$m(act)>m(obj)$	$m(act)>m(obj)$	$c(act,obj)^{t-1}-c(act,obj)^{t}>1$	—
	Reaction against exclusion	Tuning, Exclusion, Nutral, depending on the agent	—	—	—	—	—	—
Experimental parameters	Number of agents	20						
	Number of values	50						
	initial number of selected values	10						
	Max. number of selected values	15						
	Min. number of selected values	5						
	Max. number of steps	10000						
	Number of runs	10						

All agents come to belong to the same group, and neither the perpetrator nor the victim emerges in the model with tuning only(EC1).

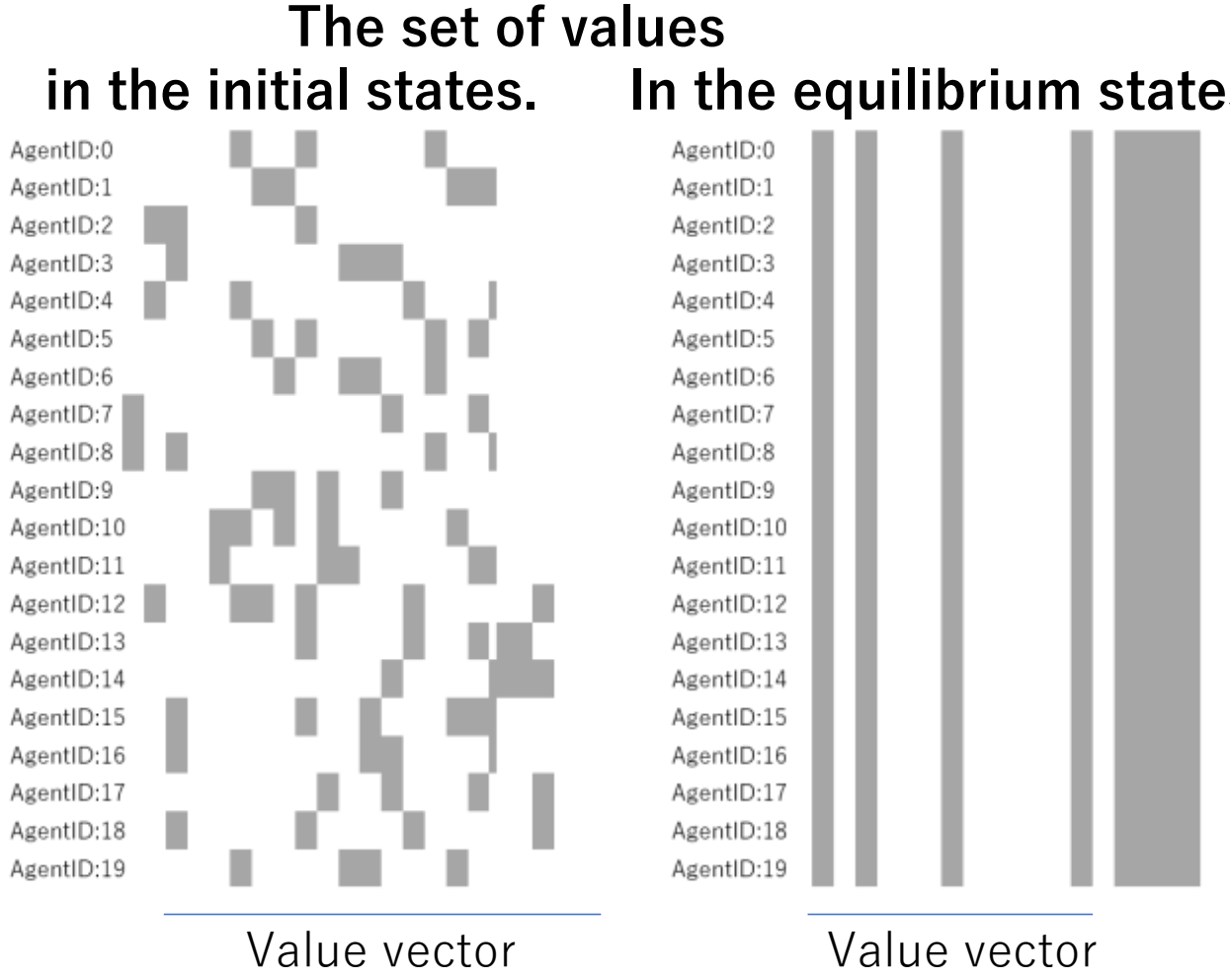


Fig. An example of the set of values for each agent in the initial and equilibrium states calculated in the model with tuning only (EC1).

Separate groups emerge, but the victim and perpetrator does not emerge as different conflicting agent in model EC2.

(Tuning: $\mathbf{p(act,obj)} > \boldsymbol{\delta}$ Exclusion: $\mathbf{c(act,obj)^{t-1} - c(act,obj)^{t} > 1}$)

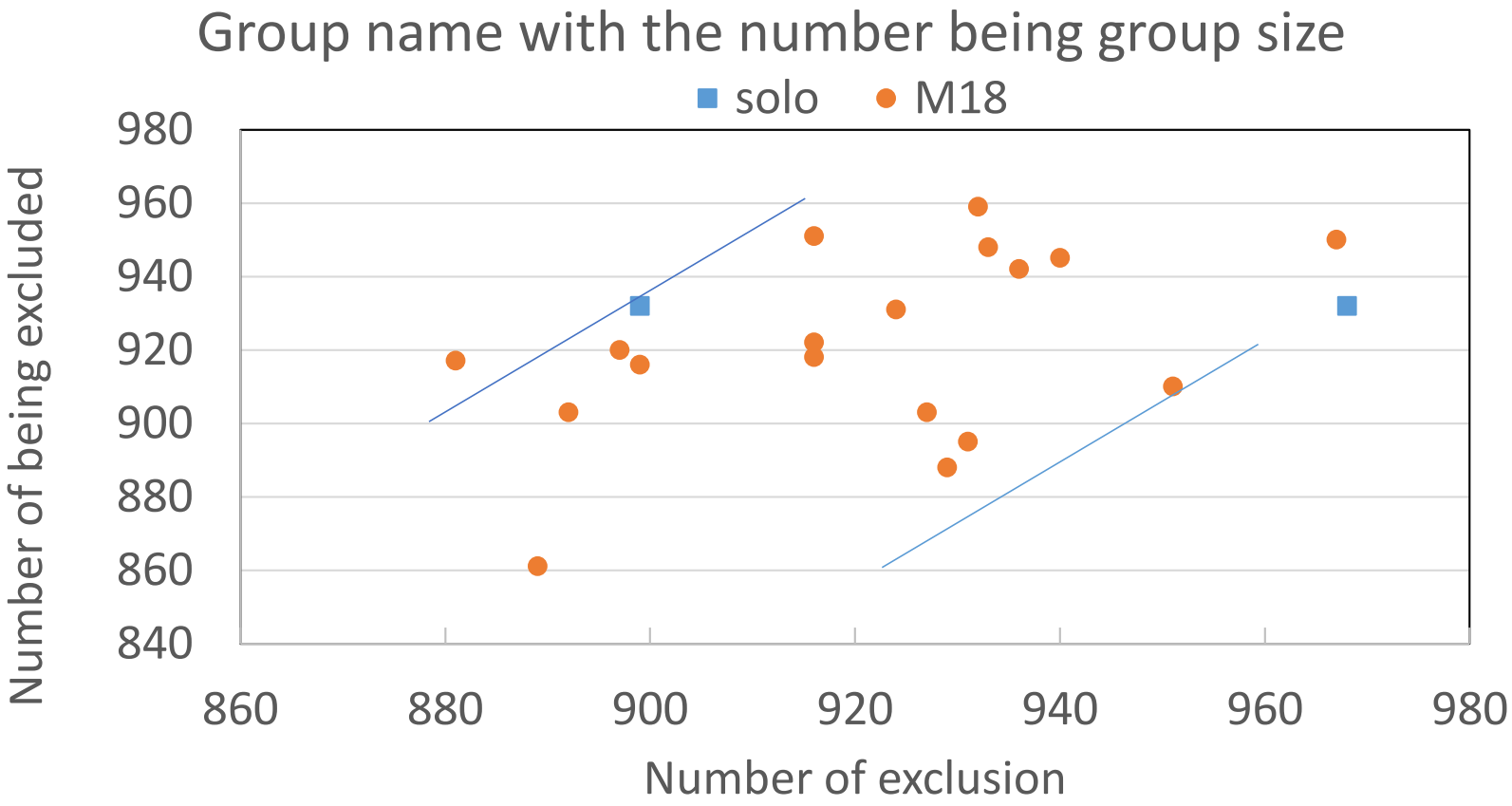


Fig. An example of the relationship between the number of excluding others and the number of times an agent is excluded by others in model EC2

The victim and perpetrator emerge as conflicting agents, but the third party does not emerge in the model EC3.

(Tuning: **p(act,obj)>δ** Exclusion: **m(act)>m(obj)**)

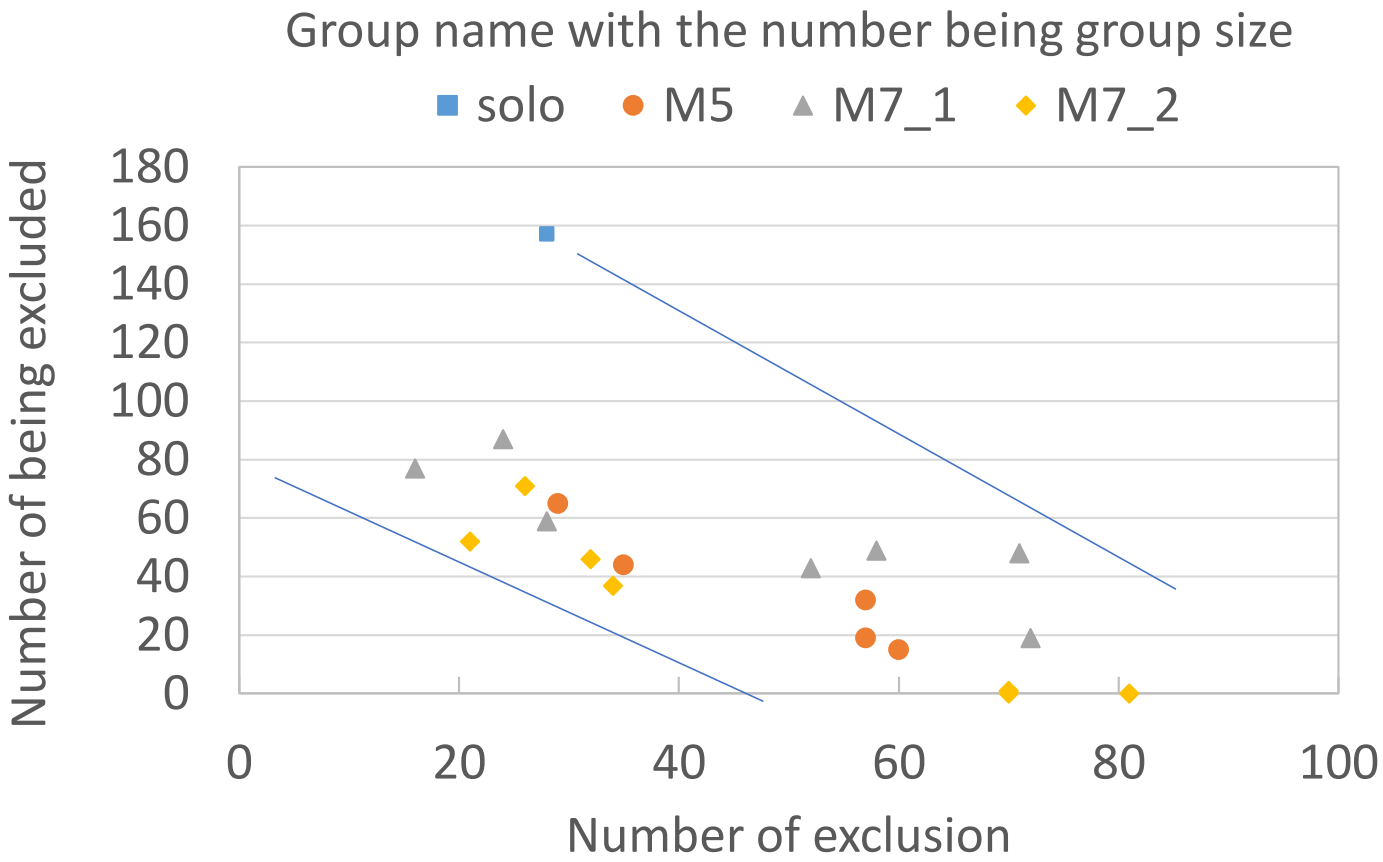


Fig. An example of the relationship between the number of excluding others and the number of times an agent is excluded by others in model EC3

The victim and perpetrator emerge as conflicting agents, but the third party does not emerge in the model EC4.

(Tuning: **$p(act,obj)>g_{act}$** (threshold value) Exclusion: **$m(act)>m(obj)$**)

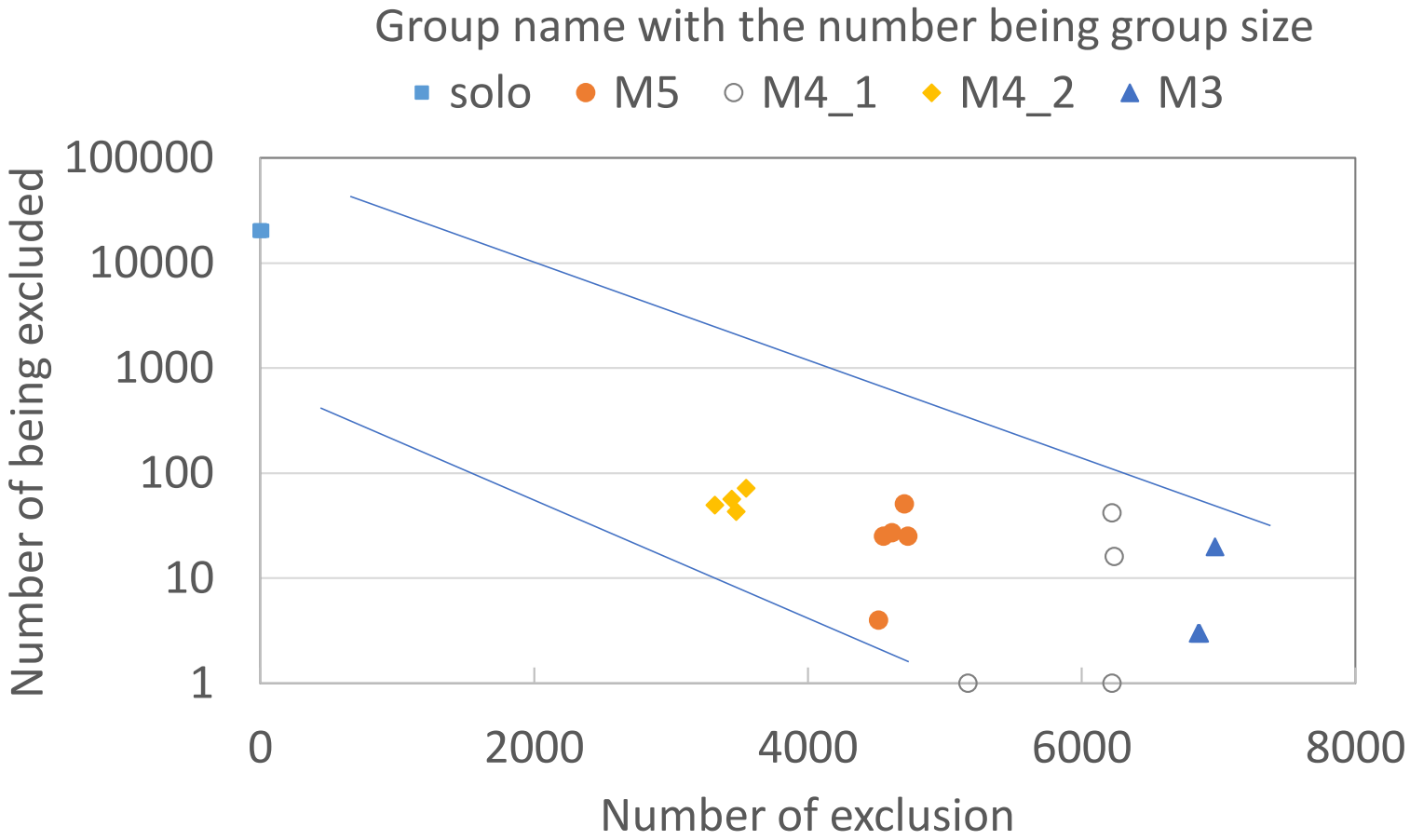
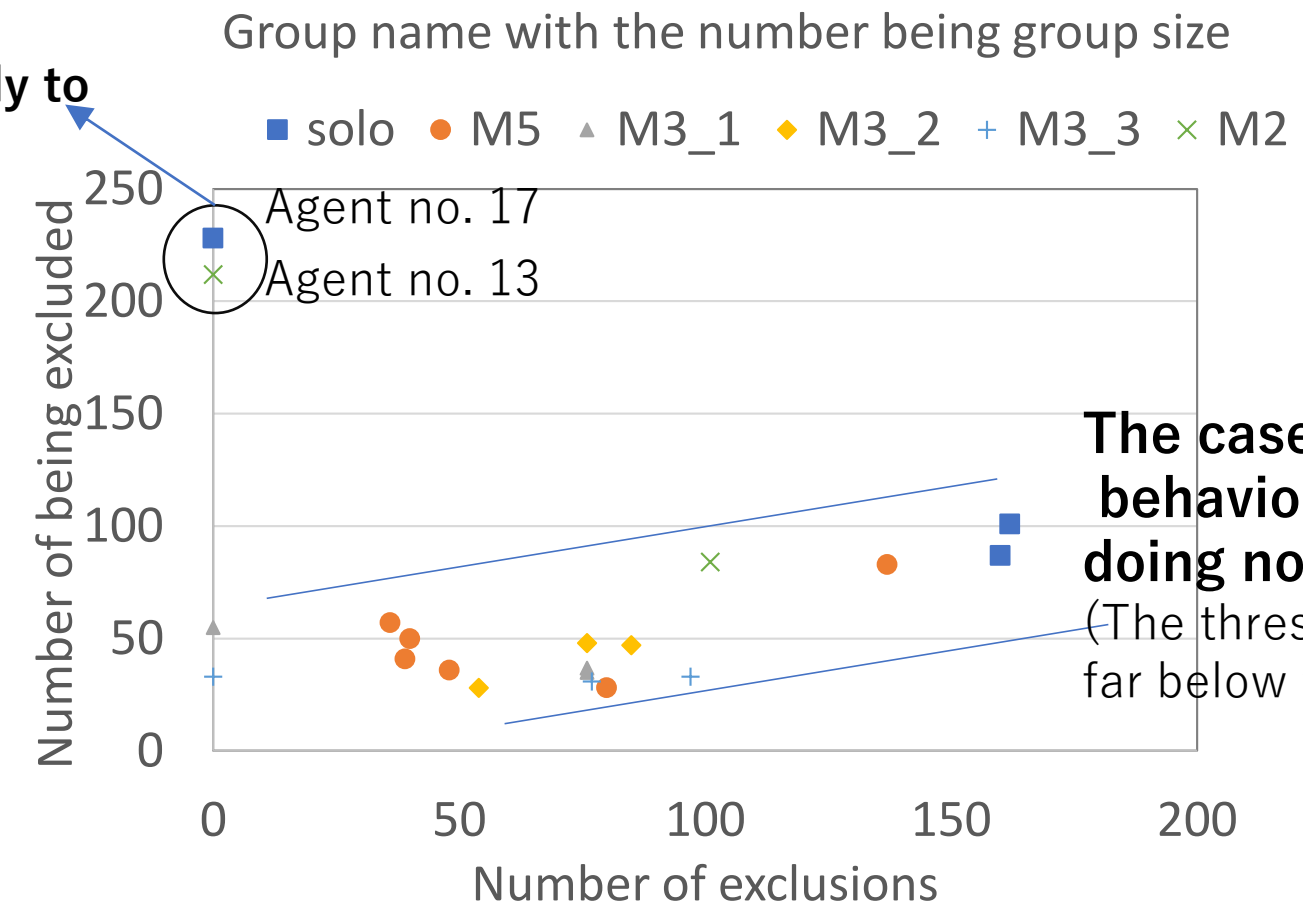


Fig. An example of the relationship between the number of excluding others and the number of times an agent is excluded by others in model EC4.

Victim agents emerge, but for most of the agents, conflicting relationship does not emerge in model EC5.

(Tuning: $p(act,obj) > g_{act}$ Exclusion: $p(act,obj) < e_{act}$)

Agents who are less likely to tune with others and less likely to exclude others.



The case where agent's behavior does not include doing nothing, substantially.
(The threshold of exclusion is not far below the tuning threshold)

Fig. An example of the relationship between the number of excluding others and the number of times an agent is excluded by others in model EC5.

The victim, perpetrator and the third party consisting of three categories emerge in the model EC6.

(Tuning: $\mathbf{p(act,obj)>g_{act}}$ Exclusion: $\mathbf{p(act,obj)<e_{act}}$, $\mathbf{m(act)>m(obj)}$)

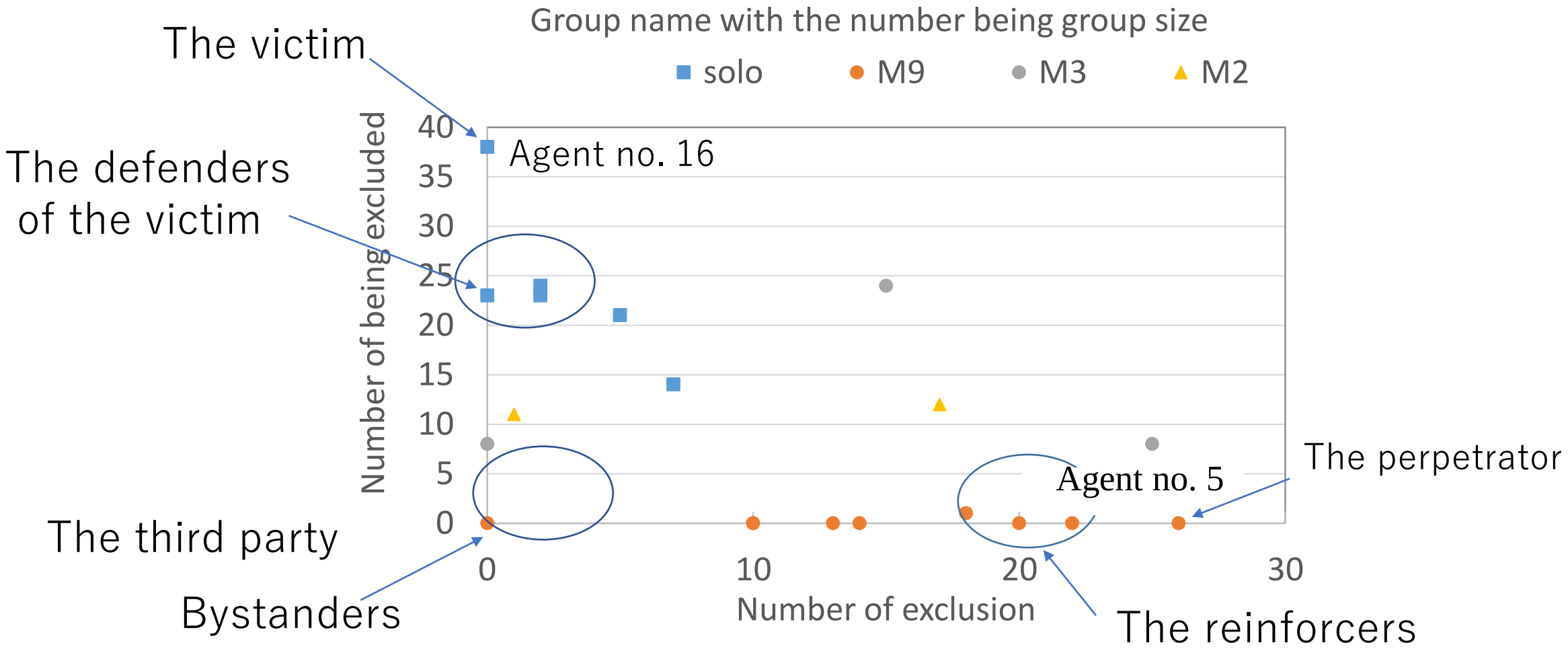


Fig. An example of the relationship between the number of excluding others and the number of times an agent is excluded by others in model EC6.

An agent who is more likely to tune with others tends to become a member of a larger group, resulting in the tendency of being less likely to be excluded.

An agent who is less likely to tune with others tends to become a solo, resulting in the tendency of being more likely to be excluded.

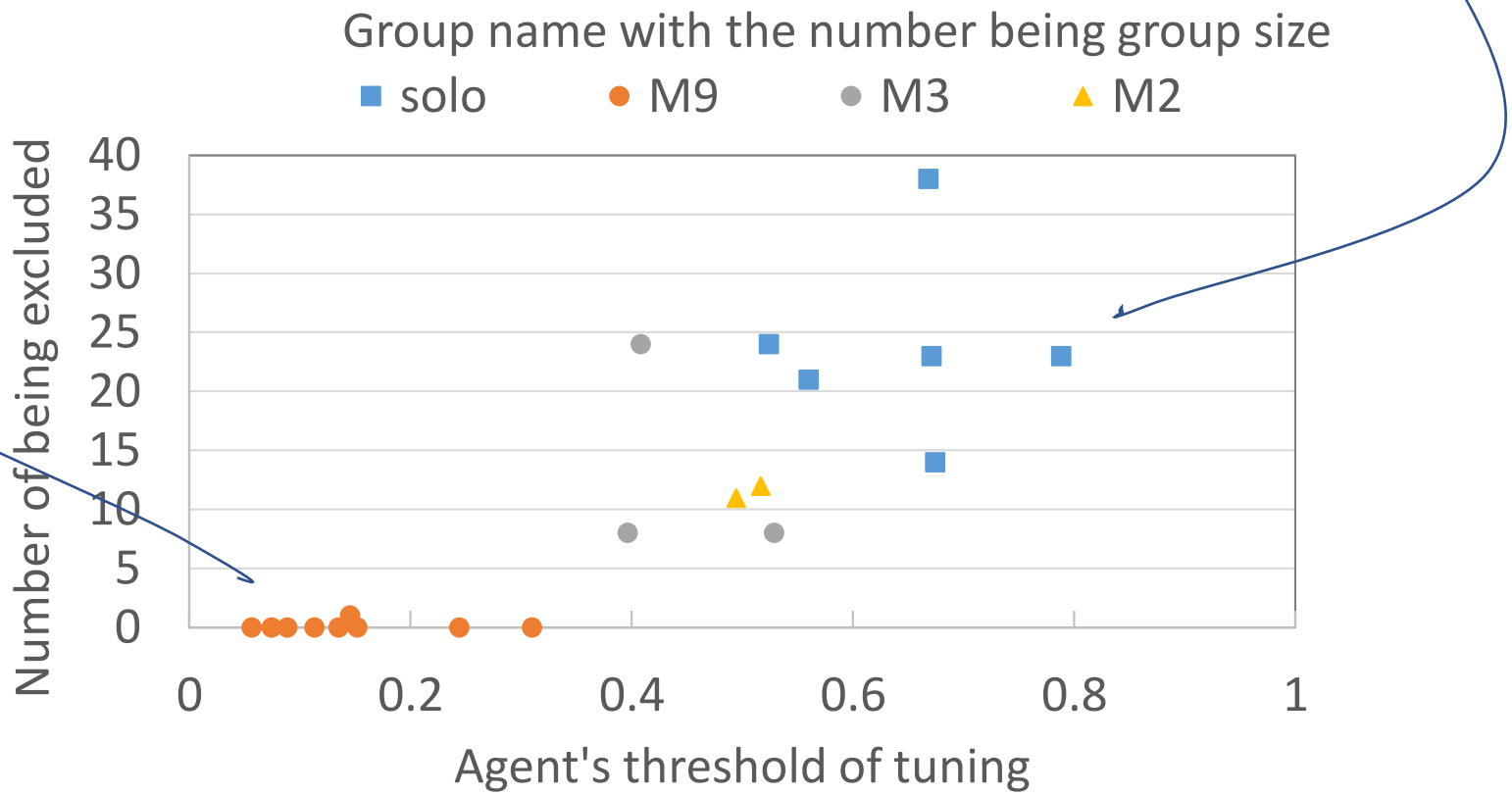


Fig. Effect of the agent's tuning threshold on the number of times they are excluded by other agents in the model EC6.

Among the solo agents, an agent who is less likely to exclude others tends to become a victim agent.

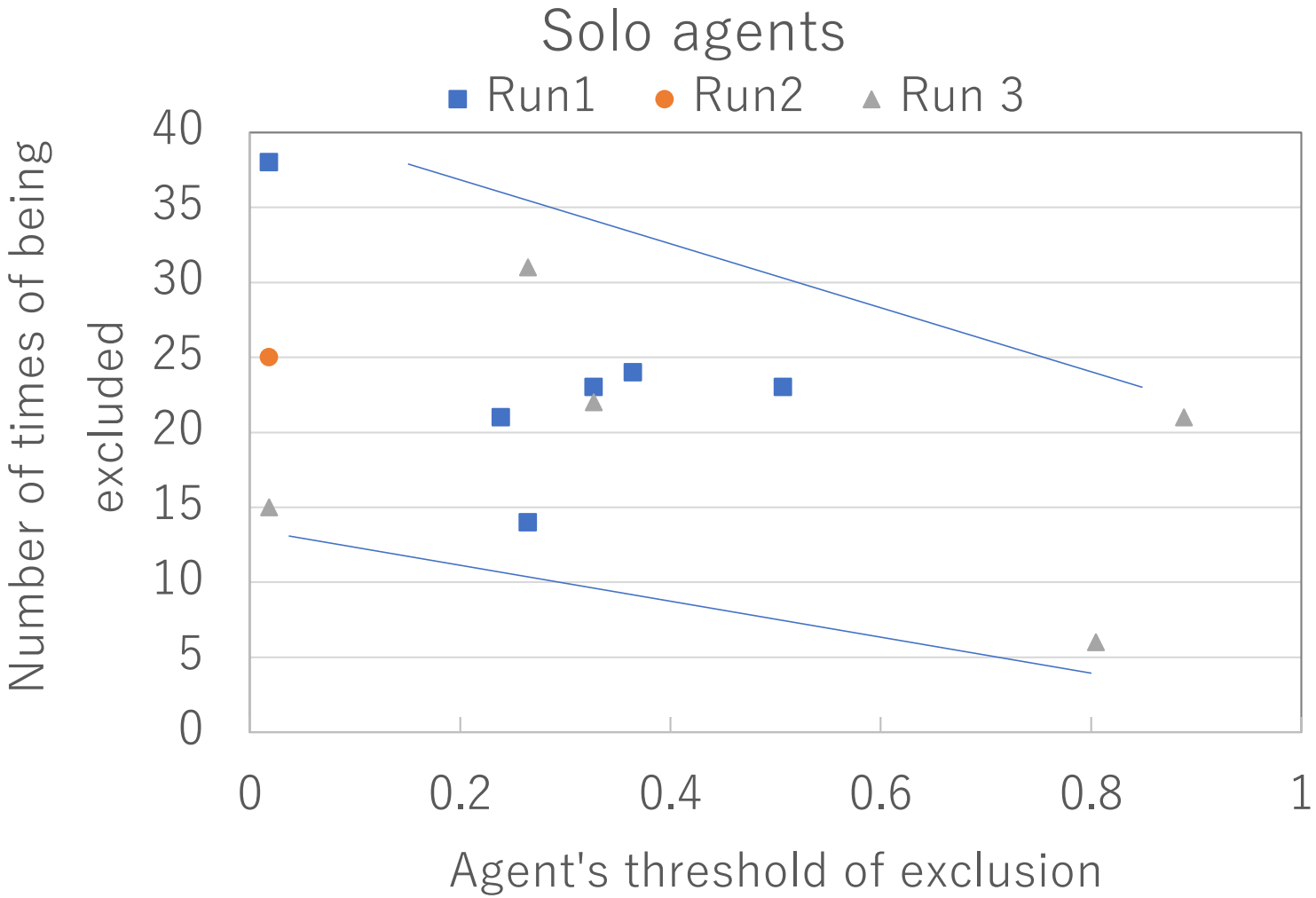


Fig. Effect of the solo-agent's excluding threshold on the number of times they are excluded by other agents in model EC6.

Agent who belongs to a larger group, as well as being more likely to exclude others is more likely to become a perpetrator.

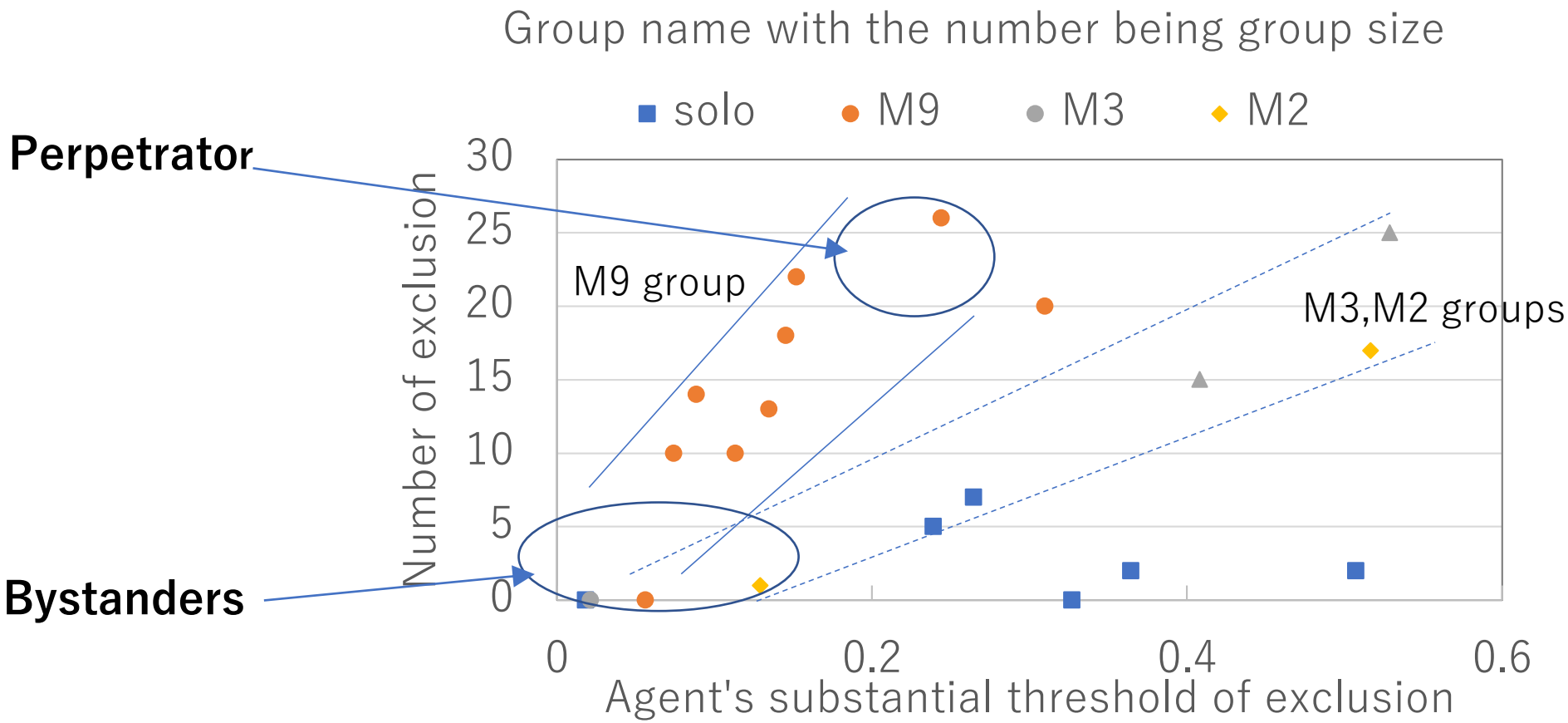


Fig. Effect of the agent's threshold of exclusion on the number of times they exclude other agents in the model EC6.

Effect of reactive action against exclusion employed in the present study (EC7) is negligibly small.

(Tuning: $\mathbf{p(act,obj)>g_{act}}$ Exclusion: $\mathbf{p(act,obj)<e_{act}}$, $\mathbf{m(act)>m(obj)}$)
Reactive action: **E**xclusion, **N**eutral(doing nothing), **T**uning)

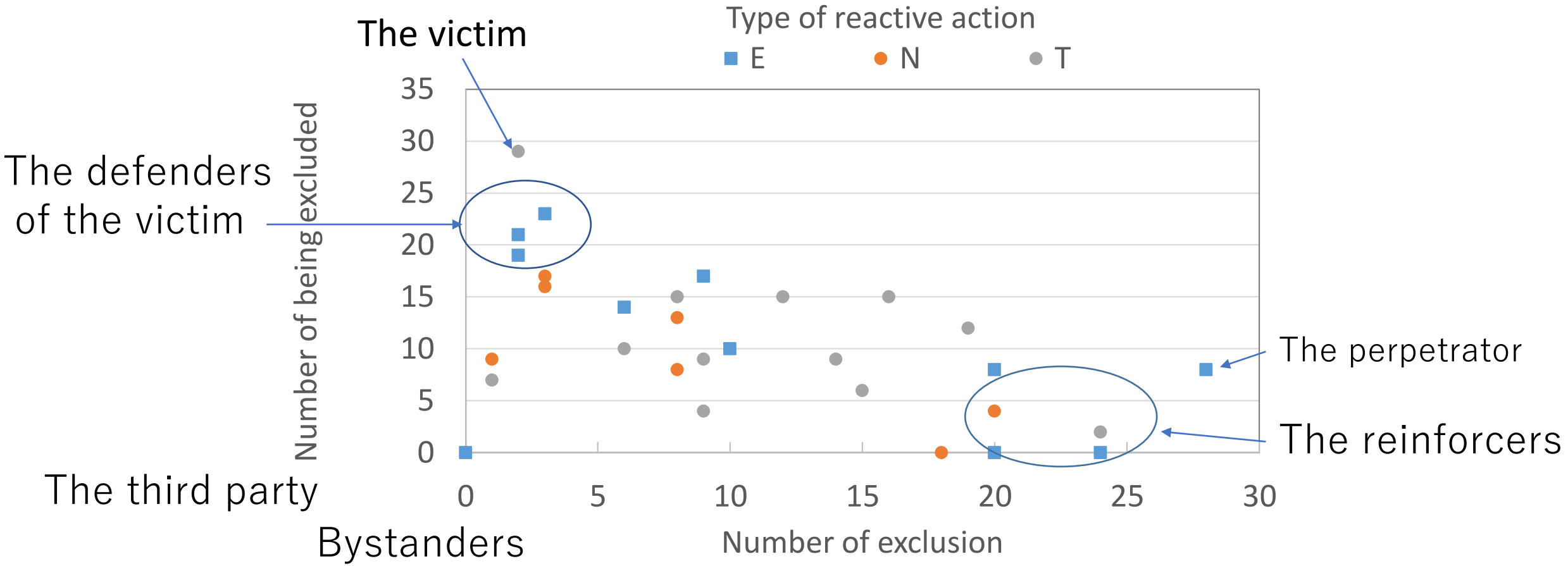


Fig. Effect of reactive actions seen in the relationship between the numbers of exclusion and cases of being excluded in model EC6.

Name of experimental condition	Behavioral rules of agent		Experimental result
	Tuning	Exclusion	
EC1	$p(act,obj)>\delta$	—	All agents come to belong to the same group, and neither the perpetrator nor the victm emerges.
EC2	$p(act,obj)>\delta$	$c(act,obj)^{t-1}-c(act,obj)^{t}>1$	Separate groups emerge, but the victim and perpetrator does not emerge as different conflicting agent.
EC3	$p(act,obj)>\delta$	$m(act)>m(obj)$	The victim and perpetrator emerge as conflicting agents, but the third party does not emerge.
EC4	$p(act,obj)>g_{act}$	$m(act)>m(obj)$	The victim and perpetrator emerge as conflicting agents, but the third party does not emerge.
EC5	$p(act,obj)>g_{act}$	$p(act,obj)<e_{act}$	The victim agents emerge, but for most of the agents, conflicting realtionship as victim and perpetrator does not emerge.
EC6	$p(act,obj)>g_{act}$	$p(act,obj)<e_{act}$, $m(act)>m(obj)$	The victim, perpetrator and the third party consisting of three categories emerge.
EC7	Same condition as EC6 plus reaction rule against exclusion		Same result as EC6. The effect of the reaction rule assumed in the present study is negligible.

Note: Three categories in the third party in EC6 and EC7 include reinforcers, the victim-sided and the third party agents.

Summary of the experimental results.

1. The emergence of the third party, as well as the perpetrator and the victim is only reproduced under the following assumption.
   - The likelihood of both the tuning and excluding actions is agent-specific.
   - The exclusion is conducted when the number of values held by the objective agent is lower than that of the active agent.

   This indicates the followings.
   - Some difference in the individual-specific tuning and excluding characteristics is the essential factor for the emergence of bullying.
   - The bullies attack their victim when they recognize that the status or power of the victim is lower than their own.

2. The type of agent to which each agent become is dependent on its tuning and excluding behavior.
   - The victim agent is a kind of agent who is less likely to tune with others as well as being less likely to exclude others.
   - The perpetrator agent is a kind of agent who is more likely to tune with others as well as being more likely to exclude others.
   - The bystander agent is a kind of agent who is more likely to tune with others while being less likely to exclude others.

Basic mechanism suggested from the result of system structure

1. The people in the organization have the tendency of tuning with others and that of excluding others as essential characteristics.
2. Due to this tendency, likelihood of being excluded is greatly dependent on the tuning behavior.
   Namely, the agent who is more likely to tune with others tends to become a member of a larger group and therefore tends to be less likely excluded.
   While the agent who is less likely to tune with others tends to become a solo agent and therefore tends to be more likely excluded.
3. In addition to the tuning behavior, the tendency of excluding others is crucial for the agent to become a candidate of the victim, the perpetrator or the third-party agents.

However, the second feature of the bullying, could not be reproduced by the present model.
This indicates that some other additional factors must exist that are responsible for of bullying. What could those factors be?

Discussion on the additional factors that are responsible for the emergence of persistent attacks by and toward the particular agents.

Some interesting hints can be found in the literature (Salmivalli, 2010, Coyne, et.al. 2000) which points out the followings.

1. The bullying behavior is motivated by **the bullies' pursuit of high status** which is enhanced by the bystander's positive feedback or reinforcement through verbal or nonverbal cues such as smiling, laughing or cheering.
2. The bullies choose their victims who are submissive, physically weak, and in a low-power position, because they can demonstrate their power to the rest of the group and renew their high-status position without the fear of being confronted.

Something related to the motivation for excluding actions such as showing oneself superior to others or the desire to control others could be responsible for the occurrence of second feature of the bullying phenomenon.

Such factors can be implemented in the present model by assuming additional rules regarding the agents' behavior, which remains as a future subject.

Countermeasure against bullying

Based on the findings and the discussion in the present study ,the following countermeasures are considered effective.

1. **Intentional tuning behavior with the victim, because it could help him/her to become a member of a group, and therefore less likely to be attacked by the bullies.**
2. **Bystanders' intentional reaction not to reinforce the bullies so that bullies cannot have positive feedback for their attacks toward the victim.**
3. **The organization's systematic management to promote the above-mentioned appropriated reactions.**
   - **Siding with the victim by the organization-side members such as teachers.**
   - **Educating bystanders that their attitude is crucial for the bullying.**
   - **Recognizing the existence of the occurrence of bullying in a group.**

Conclusions

1. Macrophenomenon associated with bullying is characterized by the two features.
   1) Emergence of 5 types of agent, namely, bullies, the bullied and a third-party consisting of bystanders, reinforcers for the bullies and defenders of the victim.
   2) Persistent and offensive attacks by the perpetrator toward the victim as particular agents.
2. The emergence of the first feature is reproduced only when we assume that each agent has the characteristic tendency of tuning and excluding behavior, and that exclusion is conducted when objective agent is weaker than the active agent. This result is consistent with the facts pointed out in the literature.
3. The emergence of the second feature is not reproduced in the present model, reproduction of which remained as a future subject.
4. Based on the findings, basic mechanism as well as the countermeasure has been proposed.
   To prevent the bullying from occurring, organizational efforts not to reinforce the bullies while siding with the victim would be considered effective.