Agent-Based Model for False Belief Tasks: Belief Representation Systematic Approach (BRSA)

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Zahrieh Yousefi①✉ , Dietmar Heinke①, Ian Apperly①, Peer-Olaf Siebers②

①School of Psychology, University of Birmingham, Birmingham, UK
②School of Computer Science, University of Nottingham, Nottingham, UK
z_yousefi@yahoo.com

Abstract. A meaningful social life relies on understanding others' minds and behaviours. The ability to reason about an individual's mental states such as beliefs and desires, and to understand and predict how these mental states shape an individual's behaviour is called theory of mind (ToM). In order to examine an individual's ToM ability, false belief tasks have been used widely in the literature.

This research is a novel attempt to clarify the basic cognitive processes shared across the different varieties of false belief tasks. For this purpose, an agent-based model has been implemented to evaluate how agents' achievement of goals in a social context is dependent on the ability to understand others' beliefs.

In our study, we offer a methodological framework for many belief-reasoning tasks called Belief Representation Systematic Approach (BRSA). BRSA is a simple and robust approach that breaks down false belief tasks into four fundamental cognitive phases, including Perception, Memory, Reasoning beliefs and desires, and Expressing others' beliefs and desires in an action. BRSA identifies a network of indispensable resources for belief representation. It also clarifies that there is a difference between 'understanding' others' beliefs and 'using' that understanding. BRSA demonstrates that false belief tasks, as a common decisive methodology for theory of mind competence, might involve more than understanding others' beliefs. Moreover, the model demonstrates that agents' understanding of others' beliefs on the micro level will lead to significant improvements in their performances on the macro level.

Key Words: False Belief Task, Theory of Mind, Belief Representation, Agent-Based Model.

1 Introduction

Humans are a social species; they understand their own and others' behaviour in their day-to-day life. Their capability to make spontaneous inferences about the invisible thoughts and feelings of others enables them to communicate. Typically, humans have theory of mind ability; the ability to take others' mental states such as beliefs and desires into account and apply this coherent information to infer their actions (Frith 2012). People distinguish others' beliefs, desires and goals from their own. They understand and predict others' actions by reasoning about their beliefs and desires. From its inception, theory of mind research has evolved with various experiments to assess different characteristics of theory of mind abilities in non-human and human children. However, one type of task, the false belief task, has been the most frequently used and has widely stimulated developmental research (e.g. Apperly 2011; Doherty 2009; Bloom & German 2000). Baron-Cohen, Jollife and Robertson (1997) introduced the 'Sally and Ann false belief task' which is identified as the standard false belief task to test children's ability in understanding others' beliefs. The scenario of the task includes two puppets: Ann and Sally, a ball, a basket and a box. The subject child being tested for belief representation watches as Sally puts the ball in the basket. Then Sally leaves the room and when Sally is out, Ann moves the ball from the basket into the box. Sally returns, and the child is asked where Sally will look for the ball. The correct answer to this question is the basket where Sally put the ball. The child needs to answer the question correctly to pass the false belief test. The general design of false belief tasks solves the behavioural aspect of understanding others' beliefs by introducing two separate beliefs about the location of an object (the ball); one is the real location of the object and another is the protagonist's (Sally's) perspective, which is a false belief about the location of the object.

The results of verbal false belief tasks, for example Sally and Ann false belief task, show that children under the age of 4 years fail the verbal false belief tasks (e.g. Wellman, Cross & Watson 2001; Call & Tomasello 2008; Wellman 2014). Verbal (explicit) false belief tasks are naturally complex, as they require the integration of linguistic information. In addition, in the process of tracking events from the protagonist's point of view, these tasks may cause disruption for children (Rubio-Fernández 2013). Thus, researchers started to design non-verbal (implicit) false belief tasks with less cognitive demands to test infants' belief representation competence. Onishi and Baillargeon (2005) developed a non-verbal false belief task for 15-month-old infants concerning the change of location of an object and measuring their looking time. The findings from this experiment and others (e.g. Southgate, Senju & Csibra 2007; Surian, Caldi & Sperber 2007; Baillargeon, Scott & He 2010; Kovács, Téglás & Endress 2010; Southgate & Vernetti 2014) indicate that infants are able to pass non-verbal false belief tasks as young as 7 months, and in any case well below 4 years old. This contradiction has been a pivotal debate in developmental literature, producing fruitful research.

Historically, the literature has expanded with the diversity of false belief tasks; however, there has been very little consensus on core principles.The design of false belief tasks sometimes contains ambiguity or complexity, which makes it difficult to accurately interpret the experimental results. Despite an increasing number of studies, false belief literature lacks a systematic approach to its basic processes, leading to confusion in many of the experiments and the results. Our study therefore seeks to clarify the processes of understanding others' false beliefs and addresses a key question: Which sets of basic processes are shared across the different varieties of false belief tasks?

The main objective of false belief tasks was to examine children's ability of recognizing the perspectives of others in contrast to a differing real world state. This might be the underlying reason why understanding others' false belief is considered as an acid test for the presence of theory of mind ability (e.g. Wellman & Bartsch 1988; Doherty 2009; Workman & Reader 2014). In contrast, Bloom and German (2000) explain two reasons why the false belief task needs to be abandoned as a test for theory of mind. The first reason given is that to successfully pass a false belief task requires abilities other than ToM. The second is that ToM ability does not require the ability to reason about false beliefs. This discrepancy in the literature drives us to explore the association between ToM and false belief tasks in more detail.

Our study presents a computational model for false belief tasks to address the above inconsistencies in the literature. It also explores some of the advantages and costs of understanding others' beliefs. For this purpose, an agent-based model called 'Belief Representation Model' (BRM) was designed to shed light on false belief's processes at both micro and macro levels. On the micro level, BRM examines the concept of belief representation, procedures and the minimum resources it might require in a dynamic environment. On the macro level, the aggregated results of BRM are comparable with the empirical effects of passing or failing false belief tasks in a virtual society; the BRM simulation results reflect the effect of understanding the beliefs of others in agents' performances.

The underpinning premise of BRM was inspired by the study of Martin and Santos (2014). In their experiment the participants, rhesus macaque monkeys, saw scenarios in which a human mediator was watching an apple moving between two boxes. They provided different scenarios of true and false beliefs about the final location of the apple for both the monkeys and the human mediator by occluding parts of the apple's movement from either the monkey or the mediator. The results suggest that monkeys fail to represent others' beliefs whereas human infants pass the experiment's test and demonstrate belief representation (Martin & Santos 2014). Martin and Santos (2016) argue that primates' belief representation is limited to the relations between mediators and information that is true and they are unable to represent relations between mediators and untrue information. They suggest that belief representation may be unique to humans as part of their core knowledge systems with automatic process that enable human infants to make sense of their physical and social environments (Martin & Santos, 2014).

In our study motivated by the experiment of Martin and Santos, we offer a methodological framework for many belief-reasoning tasks called Belief Representation Systematic Approach (BRSA). BRSA is a simple and robust approach that breaks down false belief tasks into four fundamental cognitive phases, including Perception, Memory, Reasoning beliefs and desires, and Expressing others' beliefs and desires in an action. These collective phases identify a network of indispensable resources for belief representation. BRSA clarifies the difference between 'understanding' others' beliefs and 'using' that understanding. BRSA also demonstrates that false belief tasks, as a common decisive methodology for theory of mind competence, might involve more than understanding others' beliefs. In addition, the model demonstrates that agents' understanding of others' beliefs on the micro level will lead to significant improvements in their performances on the macro level. To the best of the authors' knowledge, our paper is the first attempt to explain underlying processes of understanding the beliefs of others through an agent-based model.

2 The BRM Implementation

BRM is implemented in the Repast Simphony (Repast 2017), an integrated open source Java-based modelling platform. The Unified Modelling Language (UML) class diagram of BRM is similar to the Stupid Model (Bersini 2012) with different objectives and functions. Also, there are common features between BRM and the predator-prey model and the SugarScape model (Epstein & Axtel 1996), but they differentiate in their aims and domains. For example, BRM as a generative psychology model does not benefit from the growth or decline of the agents' populations. Moreover, statistical methods are usually required if results are very noisy and effects are not clear-cut. The parameters of BRM settings have been systematically changed and have provided clear results. Hence, the application of statistical methods is not required when interpreting the BRM simulation results.

3 BRM Methodology

BRM consists of two types of reactive agents interacting within the environment: Monkey and Infant agents. The names are based on the experiment by Martin and Santos (2014) indicating two different capabilities in regard to understanding others' false beliefs; Infant agents represent the ability to understand others' false beliefs whereas Monkey agents are able to remember and track information from the past but lack the ability to understand others' beliefs.

Agents in BRM are randomly placed in a toroidal grid space of 50 by 50 and the goal of agents is to consume food. The first neighbourhood of agents refers to the Moore neighbourhood consisting of 8 cells around them. The second and third neighbourhoods are an expansion of the Moore neighbourhood to 24 and 48 cells respectively. The agents' field of view defines the agents' visual perception in the simulation. The agents' field of movement, the area in which an agent can move, consists of the cells within the first neighbourhood. The unit of time is called the 'tick' and it is the time in which each agent's action is scheduled. Each simulation by default consists of 1,000 ticks. Throughout each simulation, the number of food in the environment remains constant in every time step.

3.1. Monkey Agents' Strategy

Monkey agents observe, collect and store information about the location of food in their first neighbourhood. They are able to remember the location of food from the previous time step. They are egocentric and lack the ability to consider others' perspectives. Monkey agents' strategy comprises three phases: collecting information, recording information and action, which is illustrated in Figure 1. In the collecting information phase, Monkey agents observe the environment and collect information about the location of the food. In the recording information phase, they store the location of the food. In the action phase, Monkey agents randomly choose food and consume it. When there is no food available, they move towards the location of the food which has been stored in their memory from the previous time step.

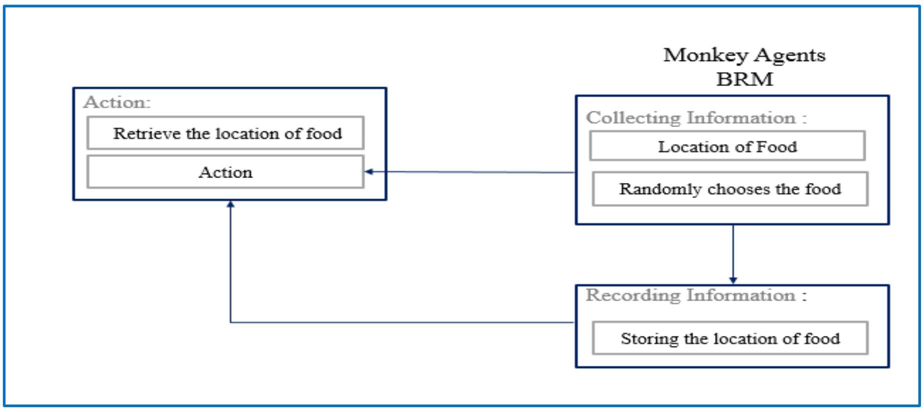

Fig. 1. Arrow and box diagram for Monkey agents' strategy

3.2. Infant Agents' Strategy

Infant agents recognize Monkey agents' beliefs regarding the location of the food. They identify all Monkey agents within their field of view that have access to the same potential food as them. Infant agents can observe up to their third neighbourhood as their field of view and only use their second and third neighbourhoods to identify the Monkey agents' perspective. Thus, Infant agents' field of view is limited to the first neighbourhood in the absence of Monkey agents. Infant agents perceive the area of Monkey agents' field of view which is shared with their own. They are able to store each Monkey agent's perspective as long as that Monkey agent exists in their field of view. Infant agents track Monkey agents' field of view and store their perspectives to create false beliefs for Monkey agents. Figures 2 and 3 illustrate two main scenarios of Infant agents' strategy regarding Monkey agents' false beliefs. The Infant agent stores this perspective. Thus, the Infant agent is able to identify the Monkey agent's false belief when another agent consumes the food registered by the Monkey agent.

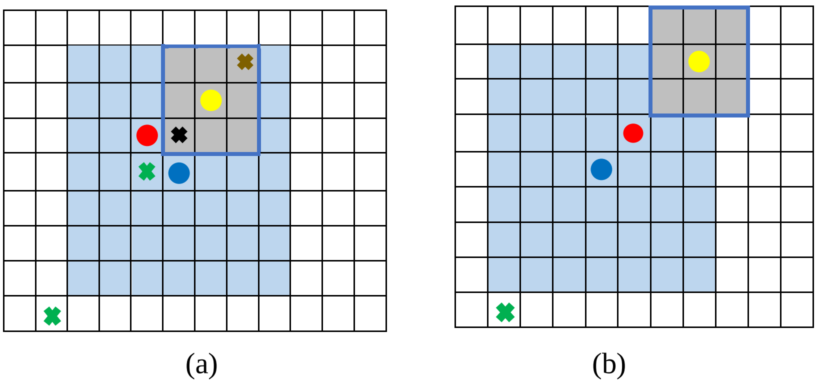

Fig. 2. Infant agents' strategy regarding Monkey agents' false beliefs

a) The Infant agent (blue circle) encounters green and black food whereas the Monkey agent (yellow circle) encounters the black and brown food in their field of view in time step t. The red agent (red circle) is another agent that has access to the black and green food.

b) The Monkey agent, the red agent and the Infant agent respectively consume the brown, black and green food. In the Monkey agent's perspective, the black food is still in its previous location.

In situations where there is more than one source of food available, the Infant agents' strategy is to choose the food that creates a false belief for the Monkey agents. Infant agents prioritize acquisition of the food based on two conditions. Firstly, that the location of the food has previously been stored in the Monkey agent's memory and in the Monkey agent's perspective, is still there. Secondly, that the Monkey agent has no alternative food in its field of view. This is called the priority function through which Infant agents apply belief representation abilities.

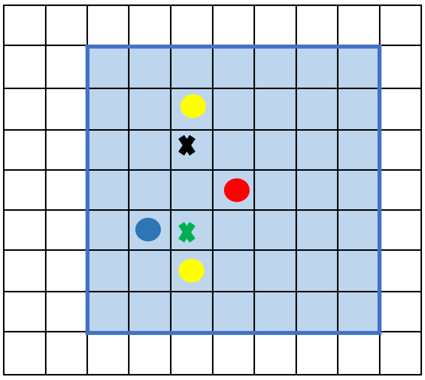

Fig. 3. Infant agents' strategy

The Infant agent (blue circle) encounters the green and black food. Note that the Infant agent has already stored the Monkey agent's perspective regarding the location of the black food. Thus, the Infant agent's priority is to move towards the black food to create a false belief for the Monkey agent (yellow circle).

The Infant agents' strategy, consisting of collecting information, recording information, reasoning process and expressing (using this understanding of) others' belief-desire phases, is shown in Figure 4 (IAD). IAD shows that Infant agents collect and reason which information to choose from their field of view, including information about the location of the food and other agents' beliefs regarding the location of the food.

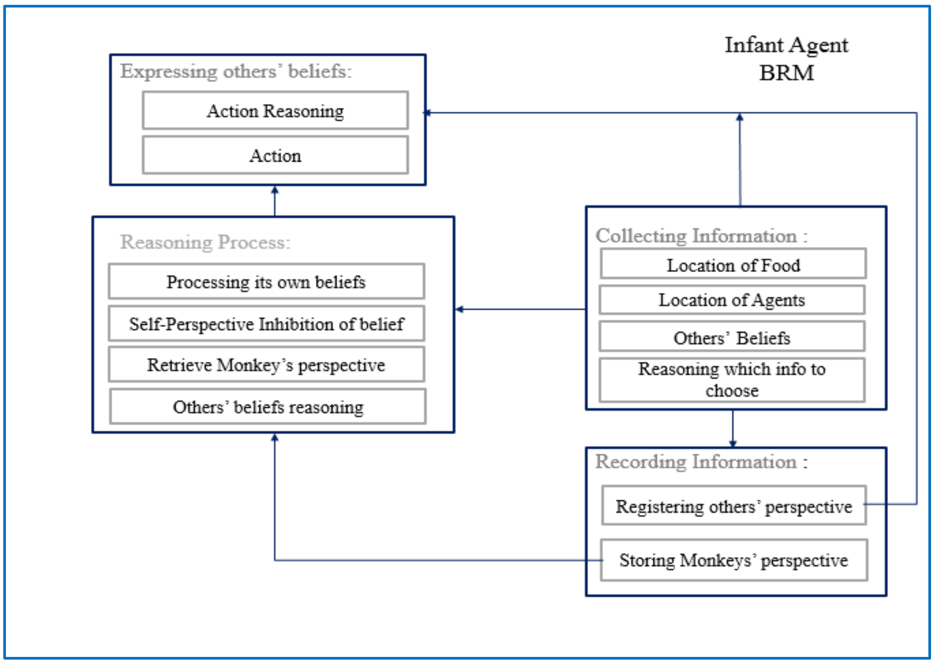

Fig. 4. Infant Agents' arrow and box Diagram (IAD)

In the recording information phase of IAD, Infant agents store the information of Monkey agents' perspective (time step t-1) and register the current location of the food which is outside the Monkey agent's field of view (time step t). Note that in registration, the access to the information is only possible at the current time step while in recording the information, it is possible to store the information for using in future time steps. The belief representation in BRM hinges on three different perspectives: the Infant agent's perspective, the Monkey agent's belief and the Infant agent's perspective of the Monkey agent's belief. The concept of time is critical in false belief scenarios in BRM; in the previous time step (t-1), all of these perspectives are identical. However, in the current time step (t), there is a contradiction between the Infant agent's perspective about the location of the food and the Infant agent's perspective of the Monkey agent's belief. In the reasoning process of IAD, Infant agents' beliefs about the location of the food is the same as the real information of the world. Nevertheless, they temporarily inhibit their own perspective, and retrieve the stored information about Monkey agents' perspectives which are in their field of view. This is considered as self-perspective inhibition of Infant agents. Given the Monkey agent's perspective regarding the location of the food, Infant agents reason about Monkey agents' desire towards the food. Finally, in the expressing others' beliefs phase, Infant agents reason and use the understanding of Monkey agents' belief in an action.

4 The Analogy between the Standard False Belief Task and BRM

The Sally and Ann false belief task is considered as the standard false belief task. The fit between the Sally and Ann false belief task and BRM is measured by comparing their corresponding critical features, which are shown in Table 1.

Table 1. A comparison between the Sally and Ann false belief task and BRM

Sally → Monkey agent	The child → Infant agent
Ann → Agent that consumes the food registered by Monkey agent	Basket → Cell
Ball → Food	Room → Field of view

Sally and Ann False Belief Task	BRM
Sally registers the location of the ball in the basket.	Monkey agent registers the location of the food in a cell.
Sally leaves the room.	Monkey agent moves to another cell and can no longer see that food, as it is outside of its field of view.
Ann moves the ball to her box.	The food which was stored in Monkey agent's memory from the previous time step is consumed by an agent.
Sally returns to look for her ball.	Monkey agent returns to look for the food.
The child is asked where Sally will look for the ball.	Infant agent reasons that if Monkey agent returns, it will look for the registered food.
If the child answers the question correctly, the child has recognised Sally's false belief.	Infant agent has recognised Monkey agent's false belief, and it sends a message to the log window of the simulation regarding the Monkey agent's false belief.

More specifically, Infant agents are analogous to the participant child, while the Monkey agents are analogous to Sally. Any agent which consumes the food that the Monkey agent registered earlier acts as 'Ann' in the task. Similar to Sally's registration regarding the location of the ball in the basket, the Monkey agent registers the location of the available food in its field of view. When Sally leaves the room, it is similar to when the Monkey agent moves, causing the food to no longer be in its field of view; both unintentionally create environments which have the potential for a false belief scenario. Moreover, similar to the child who is capable of passing the Sally and Ann false belief task, an Infant agent is able to recognize the Monkey agent's perspective and predict its desire to move towards a registered food in its memory.

There is a perspective difference between the child and Sally regarding the location of the ball. Accordingly, the perspective differences between Infant and Monkey agents are related to the location of food. The real location of the food is not the same as that in the Monkey agent's perspective because the Monkey agent is unable to update its belief about the current location of the food. In contrast, the Infant agent has access to the real information as well as the Monkey agent's perspective, both of which provide key information for the false belief scenarios. Hence, the Infant agents' belief attribution, similar to the child's belief attribution in the standard false belief task, is represented by BRM. As the interactions between agents create a number of false belief scenarios within the same time step, these belief attributions occur simultaneously for a number of Infant agents in the environment. The impact of belief attribution on social performance naturally emerges within the dynamics of BRM's virtual society. Moreover, a variety of true and false belief scenarios develop through the simulation, which is far beyond the scope of the isolated Sally and Ann false belief task.

5 The BRM Results

The setup of simulations consists of Infant agents and Monkey agents with two parameters including the number of food sources and the number of agents. The agents' average performance is calculated by running the simulation four times for each combination of the parameter values. The BRM sensitivity analysis to its initial conditions are examined by altering the parameters values in the setup. Table 2 shows the chosen parameter values. The reason for choosing these is that they correspond to a high number of Monkey agents' false belief scenarios, which is critical for evaluating the agents' performance in the context of false beliefs.

Table 2. Parameter values for BRM

Parameters	Values
Number of food (Food)	500, 600,700,800
Number of agents	400, 500, 600,700

5.1. Agents' Performances

One of the objectives of BRM is to analyse the effects of parameters on agents' performances. The number of food sources consumed by agents is used as a measurement to evaluate the agents' performances. Therefore, by comparing the performances of agents, it would be possible to identify some patterns between their performances and the concepts behind their abilities.

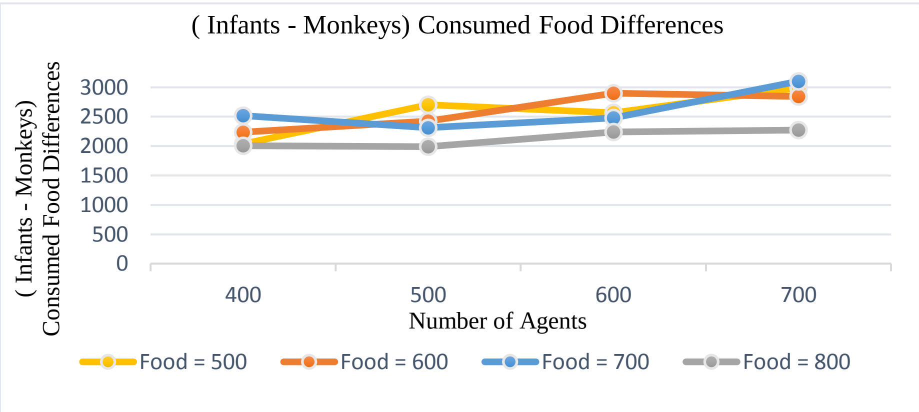

Fig. 5. The performance differences of Infant agents and Monkey agents

The difference between Infant agents and Monkey agents' performances, as illustrated in Figure 5, demonstrates that Infant agents perform significantly better than Monkey agents. The most salient difference in performance occurs when the number of each type of agent is equal to 700; nevertheless, it is primarily subject to the number of food sources. For example, when the number of food sources is 800, the differences decrease. The main reason is that the high availability of food enables the agents to consume food without the occurrence of false belief scenarios. The prominent pattern here is that differences in performance increase as the number of agents increases. However, the number of food has a great impact on this pattern.

5.2. The Number of False Beliefs of Monkey Agents

Infant agents send a message to the log window of the simulation as an output when there is a false belief scenario regarding any specific Monkey agent. At the end of each simulation run, the total number of Monkey agents' false beliefs which occurred in that run is displayed on the basis that only one false belief is recorded for each Monkey agent in each time step. The number of Monkey agents' false beliefs in the simulation starts to increase as the number of agents in the simulation setup increases (see Figure 6). The reason is that more Monkey agents are able to register the food and pursue it in the next time step. The number of Monkey agents' false beliefs is negatively correlated with the number of food sources but it is positively correlated with the number of agents. These results are consistent with agents' performance results.

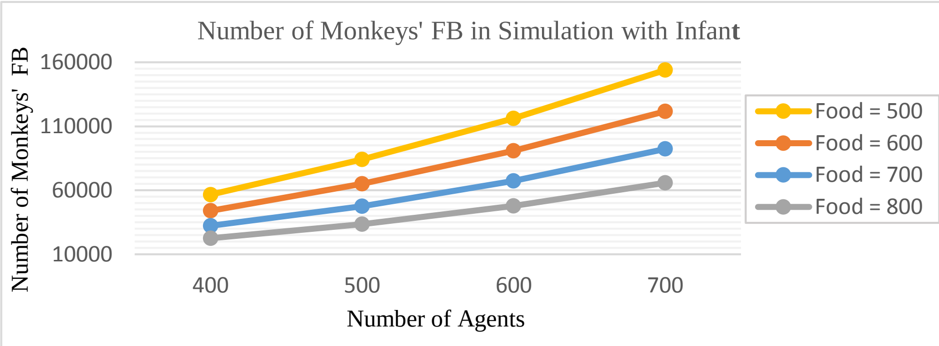

Fig. 6. The number of False Beliefs (FB) experienced by Monkey agents in the simulation with Infant agents, Food = 500, 600, 700, 800.

6 Discussion

The Belief Representation Model (BRM) consists of two types of agents: Infant and Monkey agents. Infant agents are capable of reasoning about Monkey agents' desires and beliefs, and recognize Monkey agents' false beliefs; they track Monkey agents' field of view, and register and store Monkey agents' perspectives regarding the location of food. They are also able to inhibit their own perspective regarding the location of the food and consider Monkey agents' perspectives. Thus, Infant agents are able to understand Monkey agents' beliefs about the location of the food. In contrast, Monkey agents remember and track the food from the previous time step but they lack the ability to take into account the perspective of others. Agents' decisions are influenced by their capability to consider the perspective of others and the information they perceive from their neighbourhoods. Infant agents utilize their belief representation ability and store Monkey agents' perspectives to choose food which creates false belief scenarios for Monkey agents.

6.1. Belief Representation Systematic Approach (BRSA)

One methodological approach in agent-based models is to present diagrams that illustrate the control flow and the underlying logic of the complicated and interconnected procedures of agents' actions. Figure 4, IAD, illustrates the basic underlying phases that occur for an agent with belief representation competence. The concept behind the phases in IAD provides a structured and coherent approach to belief representation processes. The collective phases are derived from the examining the behaviour and the dynamic processes of decision trees of Infant agents and is called the Belief Representation Systematic Approach (BRSA). BRSA classifies the belief representation procedure into four basic underlying phases: Collecting information, Recording information, Reasoning process of beliefs and desires and finally, Expressing mental states of others by an action. The diagram of BRSA is shown in Figure 7.

Phase 1 of BRSA: Collecting Information Phase. Infant agents collect information from their field of view in each time step including information about the location of food, the location of other agents and particularly information relating to the Monkey agents' perspective of the location of the food. Infant agents reason about the information they need to collect. They are interested in the perspectives of Monkey agents which have access to the same food as them. The collecting information phase is a central online phase which feeds other phases in BRM. Similar to the Sally and Ann false belief task question, Infant agents must answer the following questions correctly to pass the false belief test:

- Where was the location of food registered in the Monkey agent's memory (which cell)?
- Is the food still in the Monkey agent's field of view?
- Can the Infant agent consume the food which was stored in Monkey agents' memory? (Has the food been eaten by other agents?)
- Where will the Monkey agent search for the food when it returns to its previous position?

The answers to these questions will be collected through the collecting information phase in different time steps. There is a dynamic link between the collecting information phase and the other phases in regard to each false belief scenario. The collecting information phase is parallel to the time and dynamics of the world; this means that the collecting information phase is a continuous process corresponding to the time steps and environmental changes. The online raw information becomes available from the collecting information phase, which can then feed other phases, enabling them to complete their related processing simultaneously.

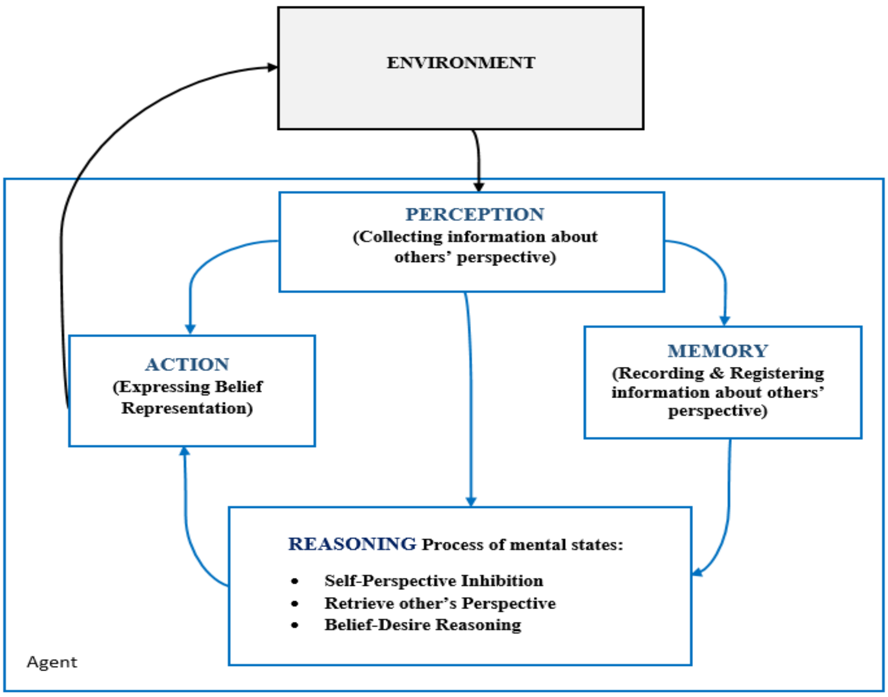

Fig. 7. Belief Representation Systematic Approach (BRSA**)**

Phase 2 of BRSA: Recording Information Phase. BRSA demonstrates that memory plays a crucial role in belief representation. Memory is indispensable for Infant agents in order to pass the false belief test. Infant agents record information about the location of food from two different perspectives: Monkey agents' perspectives and their own. Infant agents are able to switch from one perspective to another.

Phase 3 of BRSA: Reasoning Process of Beliefs and Desires Phase. The reasoning process of the beliefs and desires phase involves complex information processing. This phase demonstrates the capability of the Infant agents to understand the false beliefs of others. Conceivably, there are two different versions of beliefs about the location of the food in false belief scenarios; the Infant agents' own perspective, which is the last updated version of the reality, and the Monkey agents' perspective which is not updated from the previous time step. By default, agents use the updated information about the location of food due to the dynamics of the environment. However, Infant agents inhibit their own beliefs about the current location of the food temporarily and restore the Monkey agents' beliefs, which have already been stored. Infant agents take into consideration that other agents have a common desire towards the food. The procedure of the reasoning process of beliefs and desires includes:

- Self-perspective inhibition
- Retrieving the protagonist's perspective data from memory
- Selective processing of protagonist's (Monkey agent's) belief and desire based on its own belief and desire.

At this stage of the BRM, the Infant agent's recognition of the Monkey agent's belief is complete.

Phase 4 of BRSA: Expressing Beliefs and Desires of others Phase. There is a critical difference between having a competence and using it. This phase represents the agents' actions based on their understanding of other agents' beliefs and desires. Noticeably, expressing (using their understanding of) the beliefs and desires of others is analogous with the measurement test in false belief tasks. Infant agents utilize their understanding of Monkey agents' false beliefs in their actions. First, when the Monkey agent's belief is true, the Infant agent prioritizes consuming the food which creates a false belief for Monkey agents. Second, once the Monkey agent's belief is false, then Infant agents express their understanding of the Monkey agent's false belief by sending a message and at the end of the simulation, a message shows the total number of Monkey agents' false beliefs recognized by Infant agents.

6.2. In which conditions is False Belief Task a Decisive Test for ToM based on BRSA?

BRSA demonstrates the necessary resources for each phase of the Infant agent's understanding of others' beliefs. Firstly, the Reasoning phase demonstrates the demands on cognitive resources in the false belief task include reasoning, inhibition, recording and retrieving information about others' perspective from memory, as well as the required interconnection between the resources. Therefore, having these resources is a precondition for success in false belief tasks. Secondly, the Expressing phase demands more than understanding others' beliefs. These two reasons validate the point that false belief tasks require sufficient cognitive resources as a precondition to act as a decisive test for theory of mind. This is compatible with the literature which suggests that false belief tasks involve challenging actions, engaging with complex reasoning, intellectual connections and skills such as linguistic abilities, which might be more demanding than understanding others' beliefs.

6.3. The Effects of Belief Representation on Agents' Performances

The simulation results show that Infant agents perform consistently better than Monkey agents. Infant agents' efficiency is due to three factors. First, Infant agents' recognition of Monkey agents' false beliefs. Second, their ability to apply this understanding and information into a plan that enhances their chances of achieving their goals. Third, performing an action by employing the plan (creating more false belief scenarios for Monkey agents) increases the successful performance of Infant agents. Therefore, belief representation ability is a fundamental element in higher performance, along with other factors of reasoning, planning and contributing an action in achieving a goal.

6.4. The Network of Resources in BRSA

BRSA presents the key components of the belief representation processes, which consist of perception, memory, inhibitory control and selective process reasoning, in addition to complex reasoning resources, which are essential for the phase of expressing others' beliefs and desires. Together, these components represent a network of resources that shapes the individual's ability to understand others' beliefs. This network is compatible with the developmental literature underpinning the theory of mind network (Mohnke et al. 2015; Gallagher & Frith 2003; Carrington & Bailey 2009).

7 Conclusion

BRM is an original model which illustrates the underlying processes of understanding others' false beliefs in a structured and coherent approach by classifying this procedure into four phases called the Belief Representation Systematic Approach (BRSA). The first phase involves agents collecting information, particularly in relation to other agents' perspectives on the location of the food. The second phase, the recording information phase, is when agents store the collected information, including the perspectives of other agents, in their memory. This phase highlights the role of memory and time traveling in belief representation. The third phase, the reasoning process of beliefs and desires phase, is the main phase for processing information about others' perspectives. In this phase, agents inhibit their own beliefs temporarily and restore others' beliefs. This phase also involves critical reasoning about the beliefs and desires of others. The fourth phase, expressing others' beliefs and desires phase, is concerned with deciding on an action by considering others' beliefs and desires. This phase identifies the subtle difference between having the ability to understand the beliefs of others and using this understanding in agents' actions. BRSA validates that false belief tasks require sufficient resources as a precondition to act as a decisive test for theory of mind. Furthermore, BRSA identifies the key components of belief representation processes consisting of perception, memory, inhibitory control and selective process reasoning. These components represent a network of indispensable resources for belief representation. In addition, the performance of agents capable of belief representation is consistently higher in achieving their goals. The main factors in producing a more efficient performance in agents include a combination of understanding others' beliefs and implementing this understanding by taking action.

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