Sasaki, Yasuo; Hämäläinen, Raimo P.; Saarinen, Esa

Modeling Systems of Holding Back as Hypergames and their Connections with Systems Intelligence

Published in:
Systems Research and Behavioral Science

DOI:
10.1002/sres.2276

Published: 01/01/2015

Document Version
Peer-reviewed accepted author manuscript, also known as Final accepted manuscript or Post-print

Please cite the original version:
Sasaki, Y., Hämäläinen, R. P., & Saarinen, E. (2015). Modeling Systems of Holding Back as Hypergames and their Connections with Systems Intelligence. *Systems Research and Behavioral Science*, *32*(6), 593-602. https://doi.org/10.1002/sres.2276

SYSTEMS RESEARCH and BEHAVIORAL SCIENCE

Modeling Systems of Holding Back as Hypergames and their Connections with Systems Intelligence

Journal:	*Systems Research and Behavioral Science*
Manuscript ID:	SRES-13-0104.R1
Wiley - Manuscript type:	Research Article
Keywords:	hypergames, systems intelligence, systems of holding back, subjective games, cognitive dissonance

Modeling Systems of Holding Back as Hypergames and their Connections with Systems Intelligence

Abstract

We discuss linkages between hypergame theory and systems intelligence and examine how both perspectives can benefit one another. We argue that hypergame theory can provide a formal foundation for key premises of systems intelligence, while the philosophy of systems intelligence can present a new way to illustrate hypergame theory as a perspective in order for an agent acting inside a system to become systems intelligent. The integrated perspective elaborated here is particularly relevant in the context of certain kinds of paradoxical but ubiquitous human interactive situations called systems of holding back.

Keywords: hypergames, systems intelligence, systems of holding back, subjective games, cognitive dissonance.

Introduction

The targets of the present study are paradoxical but ubiquitous human interactive situations called "systems of holding back," which have been originally identified in the discourse of systems intelligence (Hämäläinen and Saarinen, 2004, 2006). In a system of holding back, everyone involved pictures a common desire in each mind, yet nobody behaves so as to achieve it. Consequently, the common desire does not work out, and another outcome less desirable for everyone, i.e. non-Pareto efficient outcome, is obtained. Although the definition itself can cover various kinds of social phenomena, our (as well as systems intelligence's) focus will be particularly on systems of holding back caused by discrepancy in people's subjective views about the situation.

Consider the motivating example of "Non-Rose Buying Finns," a story of a typical seasoned couple, introduced by Hämäläinen and Saarinen (2006):

> Most Finnish men do not buy roses for their wives spontaneously on normal weekdays. The wife has changed, he [a husband] feels, and is becoming increasingly negative. She is unenthusiastic about life. She never puts lipstick on at home just for him. The wife seems overtly pragmatic. He reacts, pushing down his more romantic ideas and gestures. But the same is true of the wife: the two are caught in a system of mutually holding back.

There they both aspire secretly to a more romantic life together with each other, yet it does not result. Their decisions to hold back are due to their different views of the situation and misperceptions, especially about each other's preference. The wife in the husband's view is more negative and unenthusiastic than she actually is and he reacts to such an image created by himself, and vice versa. It also can be regarded as a so-called mental model (Gentner and Stevens, 1983). On the other hand, if their real preferences had been objectified in some way, that is, if they both had known each partner really wished a romantic life, they would have had no reasons to hold back.

In our society, a myriad of systems of holding back can be noted. In business, for example, a service provider wants to offer the best service to the customers and they want to receive it as well. A value co-creation process plays an important role here (Spohrer and Maglio, 2009). However the provider may hold back active listening to voices of the customers because they give few suggestions or complaints about the service, while they may do so just because the provider does not seem to be so active to listen their opinions. Again, they both want the best service yet the value co-creation does not work out: they are also caught in a system of holding back. In general, a serious problem of systems of holding back is that people inside are not aware of the fact that they are in such systems: the husband may be thinking he is doing the best he can do. This makes it difficult for them to brake away from the systems without any conscious efforts.

Here we raise two key questions about this problematic but commonplace system with which we tackle in this paper.

1. How can people get caught in systems of holding back?
2. What can and should they do to get out of systems of holding back?

The first question is descriptive. We have already mentioned briefly the effect of misperceptions above, but will give a clearer perspective regarding it by using hypergame theory, a game theoretical framework which deals with human subjectivity (Bennett, 1977). In a hypergame, unlike conventional game theoretical models, each agent is assumed to possess each subjective view called a subjective game and make decisions according to it.

Then the second question is prescriptive. Systems thinking may work effectively in order to improve such non-functional systems but it inevitably requires what Hämäläinen and Saarinen call descriptive efforts from a standpoint of an external observer. In contrast, the systems intelligence approach provides a practical perspective for people acting inside systems to avoid getting caught in those traps. In this paper, by applying the hypergame perspective, we provide a formal interpretation of the systems intelligence approach, where we explain how a systems intelligent behavior can overcome such problematic situations. For the purpose, the conventional hypergame model will be extended to a dynamic model that deals with situations in which agents interact repeatedly. While a basic idea of the extension has been presented by Sasaki and Kijima (2010), their focus is on mathematical and technical aspects of it. We discuss carefully the connection of this kind of hypergame modeling and the philosophy of systems intelligence.

Thus the theoretical contribution of this paper is to combine hypergame theory and the systems intelligence approach and to show the linkage between them, in particular, how the both perspectives can benefit one another. We shall argue that the hypergame model can provide a formal foundation for key premises of systems intelligence, while the philosophy of systems intelligence can present a new way to illustrate hypergame theory as a perspective in order for one to become systems intelligent.

Following the introduction, the next section overviews key notions of the systems intelligence approach. Then we introduce hypergame theory and formulate systems of holding back in terms of it with the example story of "Non-Rose Buying Finns." By this approach, we present an answer to the first key question. After that, based on the hypergame modeling, we provide ideas to improve the systems with reference to discussions in systems intelligence. Thus we here address the second key question. Finally we give concluding remarks including some open questions. The focus of this paper is upon introducing ideas, concepts and philosophies.

Systems Intelligence

In this section, let us overview essential ideas of systems intelligence presented by Hämäläinen and Saarinen (2004, 2006).

Systems intelligence refers to an intelligent behavior in the context of complex systems involving interaction and feedback. Systems intelligent agents experience themselves as part of a whole, the influence of the whole upon themselves as well as their own influences upon the whole. It combines the notion of intelligence (e.g. Gardner, 1993; Goleman, 1995, 2006) with the systems thinking perspective (e.g. Senge, 1990; Jackson, 2003). Thus the systems perspective is regarded as essential, while systems intelligence focuses on some distinctive features which have been downplayed in the course of systems thinking. Here we summarize its claims which are relevant in the subsequent discussion.

Action primary, thinking secondary The systems intelligence perspective is based on a certain skepticism regarding the prospects of applying systems thinking for the purposes of actual life. More often than not, systems thinking requires one to step outside the system to the position of an external observer. Then the improvement of the system would become a grand project that requires him/her to identify and describe it from the external viewpoint with some expertise.

Systems intelligence refuses the outsider's view. It considers life with systems involves aspects that cannot be externalized and thus they have to be dealt with from within. This internal functional interface with systems is the central focus of it. "What can intelligent choice mean when you cannot step outside and sort out the options and their systemic impacts?"- this is the most important question of the systems intelligence approach. Then it aims to touch one's everyday-microbehaviorally relevant mode of thinking.

Optimism for change The underlying assumption is that many of the core beliefs of people around us do not show up in their actions. Nevertheless one has to act on the basis of what seems like the true image of things. Inevitably, we have to adjust to what we believe is the system. But maybe the system hides the true nature of the aspirations of the people involved. The optimism of systems intelligence is based on the possibility of a systemic leverage, where a minimal input can generate a huge output. Even a minor change in a system may result in a radical change because of the dynamism of the system – dynamism which typically is not identifiable nor externally observable to the full.

Inherent intelligence Systems intelligence encourages people to accept such a big picture and admit the possibility that what they see as a system might not reflect a reality, then argues this kind of humbleness would make the micro-behavioral change possible. Therefore it is not expertise but something that human beings possess inherently. What is needed to develop systems intelligence is not learning some new knowledge or methodology but just an awareness.

This is the basic line of thought in the systems intelligence literature so far. It suggests, if the husband is systems intelligent, he would acknowledge that what he sees is no more than a system he believes to be there, and look for where a systemic leverage is. Then to buy roses might be an answer for him: it might trigger a co-created renewal of the system. It is important that everyone is in the same position and thus can contribute the betterment of the system.

We consider the discourse of systems intelligence and systems of holding back has a similar spirit with hypergames. In the subsequent discussion, we regard a system of holding back as a hypergame and try to illustrate the connection of these approaches.

Hypergame Theory

The foundation of hypergame theory is non-cooperative game theory. Game theory is probably the most acknowledged mathematical framework to analyze interactive decision making involving multiple agents (decision makers). An interactive situation is described as a game with three components: the set of agents, alternatives of each agent, and each agent's preference on each possible outcome.

It commonly assumes that agents can observe an objectified situation as a game in the form of so-called common knowledge[1]. This means everyone involved agrees the game's rule. We consider the common knowledge assumption as not compatible with our observation of systems of holding back mentioned above, which deals with people who may be ignorant of some elements of the game such as each other's preferences. Therefore the conventional game models are not appropriate to capture the essence of systems of holding back.

[1] In the standard game theory, agents are supposed to know about the game as much as an analyzer unless otherwise stated (Myerson, 1991). A common knowledge is usually defined as: everyone knows that everyone knows that everyone knows, and so on. The common knowledge assumption also goes for Bayesian games, the standard model of games with incomplete information (Harsanyi, 1967). In a Bayesian game, an agent might not be sure about the other's preference, so in this sense the motivation is apparently similar to our study. For a theoretical comparison of hypergames and Bayesian games, see Sasaki and Kijima (2012).

On the other hand, hypergame theory has been proposed by Bennett (1977) as an effort to provide a new type of conceptual formulation for modeling complex decision making[2]. The idea is to use game theory but to discard with the assumption that all agents see the same game. The hypergame approach opens the case for discussing subjective aspects of the agents in question and in particular the possibility that they have a different perception of what the game is.

In a hypergame, it is assumed that agents are playing what are called subjective games. Although hypergame theory has developed in several ways such as hierarchical hypergames (Wang *et al.*, 1988, 1989) and symbiotic hypergames (Bennett, 1980; Kijima, 1996), this article will focus upon the simplest model called simple hypergames. In a simple hypergame, the subjective game of each agent is just given as a normal form game. Henceforth by the word a hypergame we mean a simple hypergame.

Modeling Systems of Holding Back as Hypergames: How Can People Get Caught in Systems of Holding Back?

Let us see how the example story of "Non-Rose Buying Finns" can be described by using the hypergame framework.

A hypergame is defined as the set of subjective games of each agent involved, and each subjective game is described in the form of a normal form game. Let us formulate the story as the hypergame illustrated in Table 1a and 1b. There are two agents involved, the husband (H) and the wife (W). Suppose they decide their attitudes, romantic (R) or non-romantic (NR), to each other when they meet. Thus they both have the two alternatives in the game.

Table 1a and 1b are the husband's subjective game and the wife's, respectively. Each game shows how each agent views the situation. In this case, they have same opinions that this game is played by the two and they both have the two alternatives, but different views about each other's preference. The numbers in the tables represent their ordinal preferences. For each outcome, i.e. each combination of each agent's alternative, (x, y) means that the husband's preference is x while the wife's is y. The bigger the number is, the more preferable the outcome is for the agent: 4 is the best while 1 is the worst.

$H \setminus W$	R	NR
R	4, 2	1, 3
NR	3, 1	2, 4

Table 1a: The husband's subjective game

[2]Recently an essentially equivalent framework called games with unawareness has been developed in the standard game theory community (Feinberg, 2012; Heifetz *et al.*, 2013). Hypergames have been studied mainly in communities such as operational research or systems engineering.

$H \setminus W$	R	NR
R	2, 4	1, 3
NR	3, 1	4, 2

Table 1b: The wife's subjective game

First let us consider the husband's subjective game. We write his interpretations of each possible outcome of the game using his internal speech. Here we can see how his preference is evaluated by himself as well as how he thinks of his wife's preference.

(R, R) i.e. (4,2): "I contribute romance, she contributes romance and because I am such a romantic guy secretly, this is the best outcome for me (4) but relatively undesirable for her (2) because she is not that romantic."

(NR, NR) i.e. (2,4): "Neither of us contribute romance, which is business as usual. Because I am a romantic guy, this is not so good for me (2) whereas for her (given that she is not that romantic), business as usual is the best outcome (4)."

(R, NR) i.e. (1,3): "I contribute romance but she does not contribute romance. This is the worst for me (1) because I feel rejected and frustrated. For her this is the second best outcome (3) because I disturb her business as usual status (which she ranks 4) with my romantic effort."

(NR, R) i.e. (3,1): "She contributes romance but I do not contribute romance. Her contributing romance is good for me but I feel a bit guilty for failing to respond. Clearly less than if had also contributed romance, this is the second best outcome for me (3). But for her this is the worst outcome (1), because she made an unwilling effort but was rejected."

Likewise, the wife views the situation in a symmetric way as shown in Table 1b. In this hypergame, they both prefer to be romantic if the opponent also contributes romance but prefers to be non-romantic otherwise. The point is that they both imagine the opponent would prefer to be non-romantic in any case, while she or he would not actually. The difference between Table 1a and 1b shows their misperceptions about each other's preference.

Then let us consider how they would make decisions under these settings. If we apply the notion of Nash equilibrium, the central solution concept in game theory defined as such an outcome in which everyone chooses the best response against the others' choices, (NR, NR) is the unique Nash equilibrium in both subjective games. Therefore, if we assume choosing an action that constitutes a Nash equilibrium as the decision making discipline for agents, it is the only likely outcome of the hypergame. That is, the husband estimates (NR, NR) to be the unique Nash equilibrium and hence chooses NR, while the wife does the same. As a result, only (NR, NR) can be considered to be realizable. This is a standard procedure of deriving solutions in hypergame analyses, and such an outcome is called a hyper Nash equilibrium[3] (Kijima, 1996).

[3]Precisely, choosing such an action that constitutes a Nash equilibrium is a somewhat strong assumption. For it has been shown that the precise implication of common knowledge of rationality and the game structure is a

On the other hand, imagine what if they do not have any misperceptions, i.e., what if they both perceive each other's preference correctly. Then such an imaginary situation is given as the game shown in Table 2, which is a normal non-cooperative game with common knowledge. It can be obtained by combining each agent's preference in the agent's own subjective game[4]. In this game, in addition to (NR, NR), (R, R) is also a Nash equilibrium. Thus now the Pareto optimal outcome in which they both contribute romance is possible to realize. The what-if analysis suggests that, in the original hypergame, their misperceptions about each other's preference keep the couple from a romantic life, namely (R, R). If they had known each other's real preferences, they could have achieved the more desirable outcome.

$H \setminus W$	R	NR
R	4, 4	1, 3
NR	3, 1	2, 2

Table 2: What-if analysis: an imaginary game

Note that the description above represents how an analyzer sees the situation. The agents themselves cannot conduct the line of reasoning in question: recall that they just believe each subjective game is the game they play and thus do not know the other's real preference. Therefore, they cannot calculate hyper Nash equilibria, and cannot conduct such a what-if analysis.

Next let us consider why the couple cannot get out of the undesirable situation. The discussion below draws upon Sasaki and Kijima (2008) who study the stability of hypergame structure from the perspective of the cognitive aspects of agents.

The point of "Non-Rose Buying Finns" is the fact that the hyper Nash equilibrium, (NR, NR), is the same as the Nash equilibrium perceived subjectively for both. This implies not only that the outcome is likely to happen but also that each agent considers the opponent's choice is just as expected. As the definition of hyper Nash equilibrium implies, this does not always hold. As a counterexample, suppose the husband believes the situation is the game shown in Table 2, while the wife's remains to be Table 1b. Then, he may choose R because (R, R) is also a Nash equilibrium in his mind, and thus (R, NR) becomes a hyper Nash equilibrium as well. Once this outcome realizes, it would bring about cognitive dissonance for the wife[5]. His choice of R is totally unexpected for her who has considered (NR, NR) is the only Nash equilibrium. Then it can lead her to change the way she perceives the game including the husband's preferences, and

rationalizable action, a weaker notion than Nash (Pearce, 1984). In our example case, only NR is rationalizable for the both agent in each own subjective game (Table 1a and 1b), thus still (NR, NR) is the only outcome likely to happen even if we adopt rationalizability as their disciplines for decision making.

[4]Note that this assumes that an agent perceives his/her own preference correctly. Matsumura and Kobayashi (2005) deal with agents who may not recognize their own preferences correctly.

[5]The concept of cognitive dissonance was originally proposed by Festinger (1957) in social psychology. It means an uncomfortable feeling caused by holding two contradictory recognitions simultaneously. He argues that when some dissonance exists, people try to reduce it by changing their attitudes, beliefs, and behaviors.

the hypergame may collapse. In this sense, we say the outcome falls into cognitively unstable: at least one agent feels such cognitive dissonance.

On the other hand, returning to the original case, the hyper Nash equilibrium, (NR, NR), is cognitively stable because it does not provide those kinds of cognitive dissonances to anyone. If we naturally suppose agents have no incentive to change their views about the game as long as a hyper Nash equilibrium with cognitive stability is played, then the hypergame remains there, no matter whether it includes misperceptions. Indeed, in our example, the misperceptions about the opponent's preferences are preserved. Yet the couple is not willing to change their views and behaviors proactively because the outcome is not cognitively problematic. They are stuck with the system of holding back, where they are not aware of the facts just described.

Repeated Hypergames

In order to discuss more clearly why systems of holding back remain there, let us then consider dynamic processes where agents interact repeatedly, while the analysis above has dealt with a static situation, namely, one-shot interaction. Let us call such a dynamic process a repeated hypergame and assume the following three things. First, each interaction in the whole process is expressed as a hypergame. For example, the husband and the wife meet and decide their attitudes periodically (e.g. He may think about getting roses for her each month.), and each time they play a hypergame like above. Second, at each period, they act based on each subjective game of the moment, and thus a hyper Nash equilibrium is played. Third, their subjective games may be updated only when they face cognitive dissonances in the sense stated above. Here we do not set any specific update rules. The point is that a hypergame structure can change when an outcome without cognitive stability is played, while otherwise it never changes.

In the long run, only some hypergames can remain as stable. This process is conceptually depicted in Figure 1, where a dot indicates a hypergame, i.e., a particular combination of subjective games. This can move up and down by efforts of agents to reduce cognitive dissonances they might face. The vertical axis means variations of hypergames in the figure. On the other hand, if everyone never feels cognitive problems, then the state is called stationary. Note that the up-down on the vertical axis does not have any significance such as 'better' or 'worse.' It is simply supposed that different levels on the axis means differences in the hypergame structure, that is, if any two dots are at different levels, it just means at least one agent's subjective game is different.

(Figure 1 is inserted here)

Figure 1: The process of repeated hypergames and stationary states

Obviously, if the agents have no misperceptions, the situation is always stationary in this sense. In the case we discussed in the what-if analysis above, they both see the game of Table

2. Therefore they perceive the same set of Nash equilibria, and thus a cognitive dissonance can never arise. Then the hypergame of "Non-Rose Buying Finns" (Table 1a and 1b) can also be understood as a stationary state. The essential point is that various kinds of hypergames, not only the case without any misperceptions but also some hypergames including misperceptions, can remain stable over the long term. The repeated hypergame framework can be used to explain a systematic mechanism that can generate systems of holding back in this way. Therefore the analysis above based on the framework and the concept of cognitive stability is our answer to the first key question raised in the introduction – "How can people get caught in systems of holding back?"

In this framework, as opposed to conventional game models that suppose objectified views for agents, an agent just possesses a tentative view, which might turn out to be cognitively problematic and if so, he/she modifies it, while otherwise it persists. The process is just like a scientist forms a theory. The vision is quite similar to a falsificationist's view in philosophy of science, according to which a scientific theory is no more than an unfalsified hypothesis (Popper, 1959). The same can be said for one's subjective view. In terms of the repeated hypergame perspective, an agent's view can be regarded as such a hypothesis about the situation that has not been falsified by any of past individual experiences. Here a falsification means such an outcome that provides cognitive dissonance.

The Way to Become Systems Intelligent: What Can and Should People Do to Get Out of Systems of Holding Back?

Based on the hypergame framework presented in the previous section, let us move on to the second key question, "What can and should people do to get out of systems of holding back?"

Hämäläinen and Saarinen (2006) say, "Systems intelligence is based on a principle of dynamic humbleness and optimism for change, which acknowledges that my perspective of others might be drastically mistaken, particularly regarding what the true aspirations of others might be." Thus, in terms of game theoretic perspective, the way to become systems intelligent opens when one acknowledges that he/she might play not a game with common knowledge but a hypergame and the current outcome might not be a Nash equilibrium but a hyper Nash equilibrium satisfying the cognitive stability. In other words, the view might not be true but rather an image that has not yet been falsified by any of his/her past experiences.

Consider the hypergame of "Non-Rose Buying Finns" again. If the husband accepts this view, he would now notice "fresh possibilities of flourishment are always there, simply because most forms of interaction have not been tried" (ibid.). Then he may try another action, R, which have never been played before: it can be implemented by buying roses for example. It would break down the stability the system has yielded as the husband's new behavior causes the wife a feeling of cognitive dissonance. Then she would change her view about the game, in particular, about his preference. As a result, they can jump to another hypergame, which may be a better-functioning system in the sense that it outputs a more desirable outcome for both. For she now may take R as well according to her new subjective view. There his first choice of R can be considerd as a systemic leverage (Figure 2).

(Figure 2 is inserted here)

Figure 2: Systemic leverage leads to change

Hämäläinen and Saarinen (2004) suggest four dimensions of changes induced by one's becoming systems intelligent[6]: mental change, perceptual change, individual behavioral change, and change in the system. The dynamic process mentioned above can be associated with them as follows:

- Mental change - the husband first accepts the hypergame perspective.
- Perceptual change - he takes into account other possibilities about the game structure, especially the wife's preference.
- Individual behavioral change - he tries other action than usual, like buying roses, expecting it would work as a systemic leverage.
- Change in the system - his new trial triggers the wife's perceptual change, i.e. she changes her way of framing the situation and consequently they can jump to another hypergame, which may be a better-functioning system.

With respect to the relevance of our hypergame modeling to the key premises of systems intelligence, we emphasize that, in order to act better, one does not need to describe fully the system in question as a hypergame. This is actually a critically distinct point as a hypergame study. For, in the hypergame literatures, analyses have been conducted in the form of ex-post expositions, what-if analyses, interventions from an outsider's view and so on, and all of them require efforts for full descriptions of situations in question. On the other hand, our approach is not a descriptive effort. The husband does not need to reveal the situation in the form of a specific hypergame. He can leave a part of the system (e.g. her real preference) as a black box. Nevertheless, it can lead to betterments of the interactive situation. Hence, all one needs is just awareness, which is an inherent ability to everyone.

Finally, we note that, if the situation is not a system of holding back, of course this kind of process may not always work. For example, now let us suppose the game of Table 1a is the 'true' game in the sense that they both see and play this game. Then the systems intelligent husband may try acting romantically. This will be received as a slight surprise (i.e. a cognitive dissonance) by the wife but not sufficient to change her behavior. For her choice of NR is now her dominant strategy in game theoretical terms, that is, it is better for her to behave non-romantically in any case. So from the husband's point of view, apparently nothing changes. He got aware of the

[6] Jones and Corner (2012) elaborate discussions on dimensions of systems intelligence.

possibility that he may have misperceived her preference, but this time the awareness was wrong and his initial perception had been correct. But remember this is not a system of holding back as the wife is not holding back but acts non-romantically just because she wants to do so.

Our point is that, if the situation is a system of holding back, the agents can improve it by becoming systems intelligent through the process described above, while it remains there for ever without any systemic leverage.

Concluding remarks

We have shown that hypergames can be used to model and analyze situations and behaviors studied in systems intelligence. Now we have got the clear connection between the both approaches. Hypergame theory can provide a formal foundation for key premises of systems intelligence. In particular, the repeated hypergame model can provide an explanation of a systematic mechanism that can generate systems of holding back. On the other hand, the philosophy of systems intelligence can present a new way to illustrate hypergame theory as a perspective in order for an agent acting inside a system to become systems intelligent. To understand and accept the hypergame perspective leads to mental change, the first dimension of systems intelligence. Although we have mainly used the example story of "Non-Rose Buying Finns," the discussion can be applied to various kinds of systems of holding back by, for instance, replacing R with some active behavior and NR with negative one in the game matrices.

We note that the framework presented here captures only one part of the philosophy of systems intelligence. For a more complete characterization of systems intelligence, there are many issues that need to be addressed. We note a number of topics among them, which are actually relatively new and essential topics in mathematical decision theory or game theory per se.

First, hypergames assume particular subjective views of agents, but, in the first place, what are the origins of such incorrect views? Why had the husband concluded his wife was unenthusiastic? This would also be a very essential question for understanding of the nature of systems of holding back. Typically almost all game theoretical models assume an agent's knowledge about the game structure is given and analyze how he acts or should act there. Kaneko and Matsui (1999) thus argue that most approaches in game theory are deductive. They, in contrast, propose inductive game theory that analyzes how an agent creates his/her subjective view based on past experiences. In addition, case-based decision theory proposed by Gilboa and Schemeidler (1995, 2001) is also notable. It is the basic idea of the theory that an agent is supposed to assess alternatives based on his/her own accumulated past decisions (called cases) and similarity between those and the current decision problem. Such new approaches can also be useful to characterize systems of holding back.

Second, would it be possible to explain why a systems intelligent agent may take a new action that has never been tried before in accordance with utility theory? This is different from one's expected utility maximization when facing a risk, for the conventional notion of risk implies the complete set of possibilities as well as probabilities that each of them can happen are known. A systems intelligent agent is just aware of the possibility that he/she might be unaware of something (but does not know what it is). The significance of modeling such a self-awareness of unawareness has been pointed out relatively recently (e.g. Dekel *et al.*, 1998; and Li, 2009), but any sufficient framework to capture this has not yet been established.

Finally, how an agent may revise the subjective view when facing cognitive dissonance is also an important question to understand how a systemic leverage can work to improve a system. The Bayesian approach, the standard technique dealing with updating of an agent's belief in economics and game theory, cannot provide a clear answer to the question because our interest is in agents who may not perceive all the possibilities relevant to the situation. On the other hand, by applying the theory of belief revision originally developed in the field of artificial intelligence (Gärdenfors, 1992), some game theorists have tried to address this epistemic issue (Gintis, 2010). It would be a big challenge to use the idea of belief revision to explain the dynamics of systems studied in the systems intelligence literatures.

References

Bennett PG. 1977. Toward a theory of hypergames. *Omega* **5**: 749-751.

Bennett PG. 1980. Hypergames: Developing a model of conflict. *Futures* **12**(6): 489-507.

Dekel E, Lipman BL, Rustichini A. 1998. Standard state-space models preclude unawareness. *Econometrica* **66**(1): 159-173.

Feinberg Y. 2012. *Games with unawareness.* Graduate School of Business discussion papers: Stanford University.

Festinger L. 1957. *A Theory of Cognitive Dissonance.* Stanford University Press: Stanford.

Gärdenfors P. 1992. *Belief Revision.* Cambridge University Press: Cambridge.

Gardner H. 1993. *Frames of Mind: the Theory of Multiple Intelligences.* Basic Books: New York.

Gentner D, Stevens AL. 1983. *Mental Models.* Lawrence Erlbaum Associates: Hillsdale.

Gilboa I, Schemeidler D. 1995. Case-based decision theory. *Quarterly Journal of Economics* **110**: 605-639.

Gilboa I, Schemeidler D. 2001. *A Theory of Case-based Decisions.* Cambridge University Press: Cambridge.

Gintis H. 2010. Rationality and its discontents. *The Economic Journal* **120**: 162-180.

Goleman D. 1995. *Emotional Intelligence.* Bantam Books: New York.

Goleman D. 2006. *Social Intelligence.* Bantam Books: New York.

Hämäläinen RP, Saarinen E. 2004. Systems intelligence: Connecting engineering thinking with human sensitivity. In *Systems Intelligence: Discovering a Hidden Competence in Human Action and Organizational Life*, Hämäläinen RP, Saarinen E (eds.). Helsinki University of Technology:

Espoo.

Hämäläinen RP, Saarinen E. 2006. Systems intelligence: A key competence in human action and organization life. *The SoL Journal* **7**(4): 17-28.

Harsanyi JC. 1967. Games with incomplete information played by Bayesian players. *Management Science* **14**: 159-182, 320-334, 486-502.

Heifetz A, Meier M, Schipper BC. 2013. Dynamic unawareness and rationalizable behavior. *Games and Economic Behavior* **81**: 50-68.

Jackson MC. 2003. *Systems Thinking: Creative Holism for Managers.* John Wiley and Sons: Chichester.

Jones R, Corner J. 2012. Stages and dimensions of systems intelligence. *Systems Research and Behavioral Science* **29**: 30-45.

Kaneko M, Matsui A. 1999. Inductive game theory: Discrimination and prejudices. *Journal of Public Economic Theory* **1**(1): 101-137.

Kijima K. 1996. An intelligent poly-agent learning model and its application. *Information and Systems Engineering* **2**: 47-61.

Li J. 2009. Information structures with unawareness. *Journal of Economic Theory* **144**: 977-993.

Matsumura R, Kobayashi N. 2005. The theoretical foundation of potential utility. In *Proceedings of the 1st World Congress of IFSR*, Kobe, Japan.

Myerson RB. 1991. *Game Theory.* Harvard University Press: Cambridge.

Pearce DG. 1984. Rationalizable strategic behavior and the problem of perfection. *Econometrica* **52**: 1029-1050.

Popper K. 1959. *The Logic of Scientific Discovery.* Hutchinson: London.

Sasaki Y, Kijima K. 2008. Preservation of misperceptions - stability analysis of hypergames. In *Proceedings of the 52nd Annual Meeting of the ISSS*, Madison, USA.

Sasaki Y, Kijima K. 2010. Hypergame modeling of systems intelligent agents. In *Proceedings of the 7th International Conference on Service Systems and Service Management*, Tokyo, Japan.

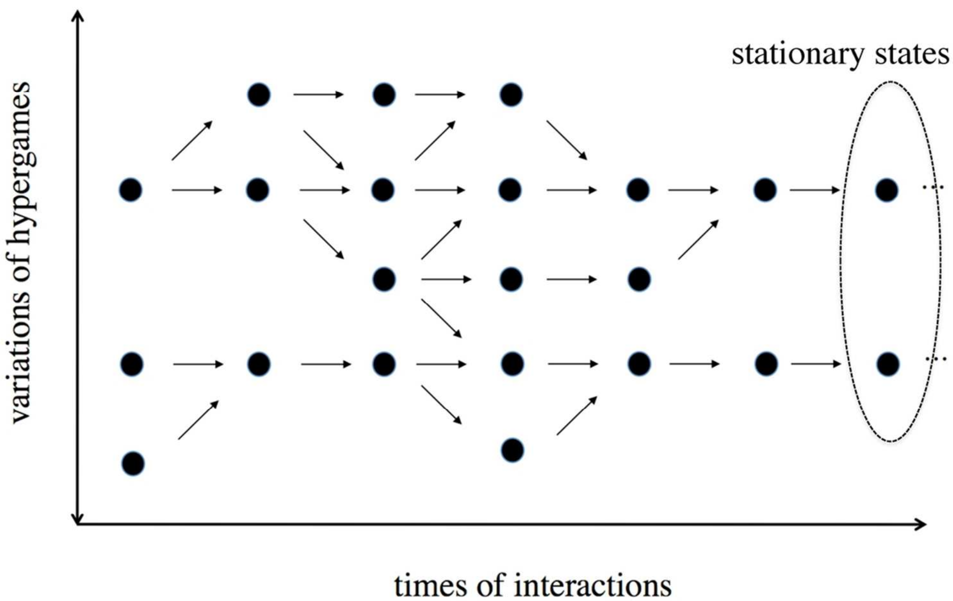
Sasaki Y, Kijima K. 2012. Hypergames and Bayesian games: A theoretical comparison of the models of games with incomplete information. *Journal of Systems Science and Complexity* **25**(4): 720-735.

Senge PM. 1990. *The Fifth Discipline: The Art and Practice of the Learning Organization.* Doubleday: New York.

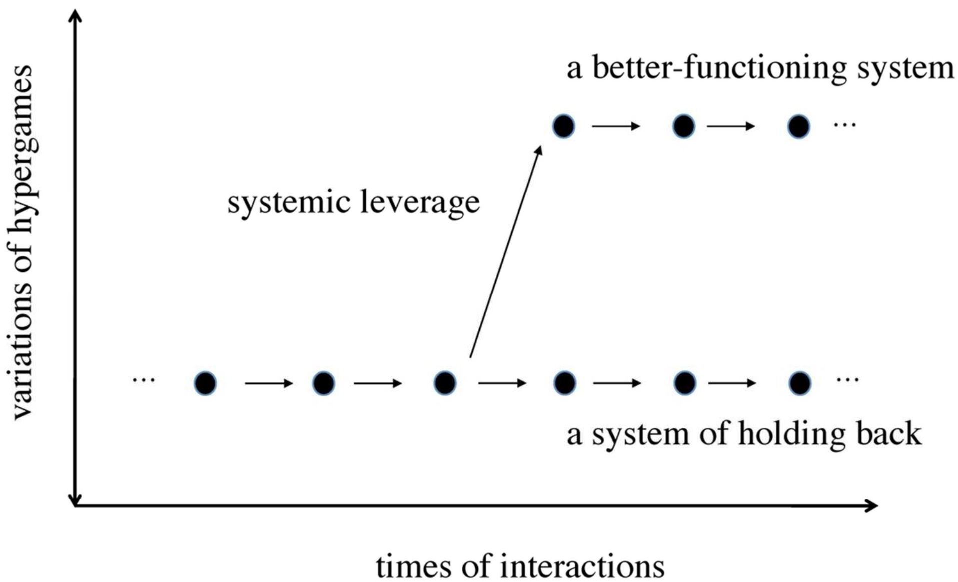
Spohrer J, Maglio PP. 2009. The emergence of service science: Toward systematic service innovations to accelerate co-creation of value. *Production and Operations Management* **17**(3): 238-246.

Wang M, Hipel KW, Fraser NM. 1988. Modeling misperceptions in games. *Behavioral Science* **33**: 207-223.

Wang M, Hipel KW, Fraser NM. 1989. Solution concepts in hypergames. *Applied Mathematics and Computation* **34**(3): 147-171.



102x64mm (300 x 300 DPI)



99x61mm (300 x 300 DPI)